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ADOPTION OF THE FOURTH INDUSTRIAL REVOLUTION TECHNOLOGIES AMONG SMALL AND MEDIUM ENTERPRISES: THE MEDIATING ROLE OF TOP MANAGEMENT SUPPORT

By

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Abstract

Despite the proliferation of the Fourth Industrial Revolution (4IR) in driving global economic growth, adoption rates remain low. Small- and medium-sized enterprises (SMEs), often constrained by limited resources and challenged by complex and disruptive technologies, struggle to keep pace with digital transformation. This study examines the relationships among technological (relative advantage, complexity, cost), organizational (firm size, top management support), and environmental (competitive pressure, government support) factors influencing 4IR technology adoption among Malaysian SMEs in the manufacturing and services sectors. It also investigates the mediating role of top management support (TMS) and profiles SMEs' strategic archetypes. Data were collected from 182 SMEs through a bilingual online survey and analyzed using Statistical Package for the Social Sciences (SPSS) 28 and SmartPLS 4. All factors, except cost, significantly influenced 4IR technology adoption. Likewise, TMS significantly mediated all relationships except cost. These findings offer valuable insights for policymakers and business leaders to optimize resource allocation and realize financial and economic gains. For SMEs, top management must adopt a visionary role by recognizing the long-term benefits of technology, aligning them with strategic objectives, and mobilizing resources to overcome adoption barriers. Additionally, SMEs should reconceptualize cost as a strategic investment supported by measurable return-on-investment indicators. Given the prevalent perception that cost is a key deterrent, the study's contrasting findings underscore the need for more targeted and comprehensive government policies that extend beyond broad-based financial assistance. Finally, nearly half of the Malaysian SMEs were classified as Analyzers, representing the ideal strategic archetype for 4IR adoption. Considering SMEs' resource constraints, government support should prioritize capacity building for top management to enable more firms to adopt the Analyzer strategy, balancing innovation for profitability with operational efficiency.

Keywords: 4IR technology adoption, Diffusion of Innovation (DOI) Theory, Technological-Organizational-Environmental (TOE) Framework, SMEs, Miles and Snow Strategy Typology

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Abstrak

Walaupun Revolusi Industri Keempat (4IR) semakin pesat memacu pertumbuhan ekonomi global, kadar penerimagunaannya dalam kalangan perusahaan kecil dan sederhana (PKS) masih rendah. PKS berdepan pelbagai cabaran untuk mengikuti arus transformasi digital disebabkan oleh sifat teknologi yang kompleks dan disruptif, selain kekangan sumber yang terhad. Kajian ini menilai hubungan antara faktor penentu dalam konteks teknologi (faedah relatif, kompleksiti, kos), organisasi (saiz firma, sokongan pengurusan atasan), dan persekitaran (tekanan persaingan, sokongan kerajaan) terhadap penerimagunaan teknologi dalam kalangan PKS sektor perkhidmatan dan pembuatan di Malaysia. Sokongan pengurusan atasan turut diuji sebagai pemboleh ubah pengantara dalam hubungan tersebut. Selain itu, kajian ini juga meninjau profil tipologi strategi PKS. Data daripada soal selidik dwibahasa dalam talian yang melibatkan 182 responden telah dianalisis menggunakan *Statistical Package for the Social Sciences* (SPSS) versi 28 dan SmartPLS versi 4. Hasil analisis menunjukkan bahawa semua faktor, kecuali kos, mempunyai hubungan yang signifikan secara langsung serta melalui peranan sokongan pengurusan atasan sebagai pemboleh ubah pengantara dalam penerimagunaan teknologi 4IR. Dapatan kajian ini memberi panduan kepada penggubal dasar dan organisasi untuk mengoptimumkan peruntukan sumber bagi memaksimumkan keuntungan kewangan dan ekonomi. Pengurusan atasan PKS perlu berwawasan dalam menyelaraskan manfaat jangka panjang teknologi dengan objektif strategik serta menggerakkan sumber secara berkesan bagi mengatasi halangan penerimagunaan. PKS juga disaran melihat kos penerimagunaan 4IR sebagai pelaburan strategik dengan pulangan yang jelas, tidak sekadar perbelanjaan. Walaupun kos sering dianggap penghalang utama, dapatan bercanggah ini menuntut dasar kerajaan yang lebih bersasar dan komprehensif. Analisis turut menunjukkan hampir separuh PKS di Malaysia tergolong dalam strategi *Analyzer*, yang paling sesuai bagi penerimagunaan 4IR. Oleh itu, kerajaan perlu memperkukuh kapasiti pengurusan PKS agar strategi *Analyzer* dapat diamalkan secara meluas untuk menyeimbangkan inovasi, keuntungan, dan kecekapan operasi.

Kata kunci: Penerimagunaan teknologi 4IR, Teori Penyebaran Inovasi (DOI), Kerangka Teknologi-Organisasi-Persekitaran (TOE), PKS (Perusahaan Kecil dan Sederhana), Tipologi Strategi Miles dan Snow

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Juz 30/Hizb 60 - Page 596: The Relief (94:5)

فَإِنَّ مَعَ ٱلۡعُسۡرِ يُسۡرًا ٥ إِنَّ مَعَ ٱلۡعُسۡرِ يُسۡرًا ٦

So, surely with hardship comes ease. Surely with that hardship comes ˹more˺ ease.

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List of Abbreviations

4IR – Fourth Industrial Revolution

ASEAN – Association of Southeast Asian Nation

BDA – Big Data Analytics

DOI – Diffusion of Innovation (DOI) Theory

DSTIN – National Policy on Science, Technology and Innovation 2021-2030

DX – Digital Transformation

FMM – Federation of Malaysian Manufacturers

GDP – Gross Domestic Product

I4.0 – Industry 4.0

Industry4WRD – National Policy on Industry 4.0

MDEC – Malaysia Digital Economy Corporation

MEDAC – Ministry of Entrepreneurship Development and Cooperation

MITI – Ministry of Investment, Trade and Industry

MOSTI – Ministry of Science, Technology and Innovation

SME – Small- and Medium-sized Enterprises

MTDC – Malaysia Technology Development Corporation

MSC – Multimedia Super Corridor

MyDIGITAL - Malaysia Digital Economy Blueprint

OECD – Organisation for Economic Co-operation and Development

ROI – Return On Investment

PLS-SEM – Partial Least Squares Structural Equation Modeling

TOE – Technology-Organization-Environment Framework

VUCA – Volatility, Uncertainty, Complexity, Ambiguity

XaaS – Anything as a Service

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CHAPTER ONE
INTRODUCTION

1.1 Background of Study

In the world of digitalization, everything happens with the touch of the fingertips or a click away. Companies are expected to thrive in an era full of volatility, uncertainty, complexity and ambiguity (VUCA) (Schoemaker et al., 2018; Vogel & Hultin, 2018), resulting in a brittle, anxious, nonlinear and incomprehensible (BANI) world (Kruse, 2025). Additionally, the world is embarking on a second information technology (IT) wave that defines the fourth industrial revolution (4IR) (Lee et al., 2018). 4IR can be described as the advent of "cyber-physical systems" involving entirely new capabilities for people and machines (Luo & Zahra, 2023; Schwab, 2017) that started in the manufacturing sector as Industry 4.0. These technologies, such as artificial intelligence (AI), were built upon the information communication technology (ICT) revolution of the mid- to late-20th century that pave way to tremendous progress in personal computers and the internet (Uctu et al., 2024). In simple terms, the advancements that set apart these 4IR technologies are characterized by vast interconnectivity and integrated with big data analytics via the Internet, making systems more flexible and intelligent, and enterprises becoming more efficient and competitive (United Nations, 2022).

4IR is rapidly changing the world's landscape (Luo & Zahra, 2023) at unprecedented speed and magnitude of transformation (Caragea et al., 2024; Zaidan & Ibrahim, 2024); to the extent regulators are struggling to keep up with oversight and enforcement of industries (Arner et al., 2017; Zaidan & Ibrahim, 2024). As a result, regulators such as those in the financial industry have no choice but to respond by

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using the same 4IR technologies that caused the disruption. Financial technology (fintech), and regulatory technology (regtech) were introduced, and regulators set up regulatory sandbox to enable innovation without compromising financial stability (Arner et al., 2017; Zaidan & Ibrahim, 2024). Meanwhile, companies, at a minimum, are expected to invest in automation and use 4IR technologies such as cloud computing, AI and mobile applications services, 3D printing, sensor technologies, 5G and Internet of Things (IoT) to remain competitive (M. F. Ahmad et al., 2024). In essence, the disruptive nature of 4IR is made possible by the capabilities that are available now; yet industries and regulators alike are grappling to keep pace with its exponential rate of advancements.

Increasingly so, the proliferation of these 4IR technologies affected our lives and the way we work across the world, at times in novel and unpredictable ways (OECD, 2019b), affecting productivity and labor force (Zervoudi, 2020). Up and coming new "markets" such as AI, e-commerce platforms and shared economy are seen flourishing, which subsequently would result in economic growth. For instance, PwC Global Estimates' Global Trade Analysis Project or GTAP (PwC, 2017) database economic model projected that by 2030, AI could boost global economic impact by up to USD15.7 trillion via effects of increased productivity and consumption-side.

It is undeniable that through the adoption of 4IR technologies, the digital economy has and will expand faster. Greater use of ICT has also been associated with higher GDP per capita. To put into perspective, in 2023, digital economy contributes over 23.5 percent of national GDP, at 3.9 percent growth rate (Department of Statistics Malaysia, 2024b). Thus, countries, developing economies in particular, have been trying to fast

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forward their transformational initiatives via ICT; and now, in recent times, the initiatives have expanded to digital economy and 4IR-related policies (Mitra, 2019). Realizing this, several governments have launched 4IR-related policies pre-pandemic COVID19, such as Germany, France, the People's Republic of China (China), South Korea (the Republic of Korea – ROK), Indonesia, Thailand and Malaysia (Asian Productivity Organization (APO), 2019; Liao et al., 2018). These governments understand that technological advancement is the primary driver of productivity growth and will improve standards of living for the people (Asian Productivity Organization (APO), 2024).

Over time, there are also technology-specific policies such as National AI Policy formulated by countries such as Malaysia, the Republic of Singapore (Singapore), and South Korea (Economic Planning Unit Malaysia, 2021a; Government of South Korea, 2020; Government of the Republic of Singapore, 2023). Currently, there exists more than sixty nations have different variations of regulatory and national policies on AI (Hohman, 2025). As these nations pursue sustainable development, economic resilience and societal aspirations (Asian Productivity Organization (APO), 2024), it is imperative that they too deliver public services through digital means to meet citizen's expectations, improve transparency and most importantly, revive the economy (Subramaniam, 2020) post-pandemic (Asian Productivity Organization (APO), 2024).

Against this backdrop, small and medium enterprises' (SMEs) digital transformation ability to face and survive VUCA is a major concern. SMEs represent approximately 90 percent of business establishments, provide employment to more than 70 percent

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and contribute up to 50 percent of GDP worldwide (United Nations, 2024). With nations moving forward with the 4IR policies to gain comparative advantages, SMEs are key for delivering sustainable productivity and inclusive economic growth. Unfortunately, SMEs worldwide are still lagging in digital transformation, citing limited financial resources as the main reason to hindering adoption, even during the pandemic (The World Bank, 2023). What is more alarming was the second top reason given by SME companies of all sizes, which was that there was "no need" to invest in digital solutions during the pandemic (The World Bank, 2023).

In Malaysia, the national adoption rate for 4IR is about 15 to 20 percent, but predominantly by large companies (Shahzad et al., 2023). Even after a year after launching Industry4WRD, a national policy on 4IR targeting the manufacturing sector, complete with zero-cost program for 4IR readiness assessment and intervention funds for Malaysian SMEs, less than 21 percent has implemented it. Hence, it is imperative for governments to re-examine their policies towards facilitating SME digital transformation (Cirera et al., 2022; The World Bank, 2023). This is to enable SMEs to harness the benefits of digitalization such as increasing market reach, revenue; gaining higher efficiency and productivity; and lower costs of doing business (M. F. Ahmad et al., 2024; Jayeola et al., 2022).

Top management support also plays a visionary role, recognizing the long-term benefits of technology adoption and aligning them with strategic goals (Chanias et al., 2019). It is incumbent upon the management's commitment and leadership skills in driving SMEs' digital transformation and innovation, including allocating limited resources necessary, overcoming barriers to adoption, as well as upskilling employees

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to ensure successful implementation (M. F. Ahmad et al., 2024; Jayeola et al., 2022). It would also be beneficial to have knowledge concerning a company's strategic type given that it could inform top management's role in undertaking digital transformation in the company (Anwar et al., 2025).

1.2 Problem Statement

As a small and open economy, Malaysia is highly involved in the global value chain and is striving towards becoming a high technology-based economy within the next decade (Economic Planning Unit Malaysia, 2021b; The World Bank, 2021). 4IR technologies have been proven to future-proof business, revolutionize industries and spur creation of new market opportunities, however, many companies refrained from implementing it (Pringle, 2020; Subramaniam, 2020; Tech Collective, 2020). SMEs in Malaysia constitute 96.9 percent of business establishments; contribute almost 40 percent of GDP and employ 50 percent of workforce (Department of Statistics Malaysia, 2024c). Despite their importance, exports and productivity of SMEs have yet to rise significantly (Kuriakose, 2020). Despite government intervention to provide a robust ecosystem, readiness assessment, and matching grants provided to Malaysia SMEs, the technology uptake is still mediocre (World Bank, 2020).

The impact on companies that choose not to adopt 4IR technologies and embrace digital transformation quickly could exacerbate what was seen at the onset of the pandemic that led to an economic shutdown (Subramaniam, 2020; Tong & Gong, 2020). Worse, without embracing technological advancements, these SMEs may no longer be relevant in the global value chain, and be displaced by companies that did. Even those that are aware of and attempting to embark on a digital transformation

journey are unclear on how to start and face challenges as they find the process as well as the technology to be complicated and costly. This stems from top management who lack the capabilities to understand determinants of technology adoption in order to overcome these obstacles and provide support for proper implementation (Abu Hassan et al., 2023; Maroufkhani et al., 2023). Moreover, the government is unable to allocate resources optimally and policy initiatives become countereffective. All these will derail economic development and adversely affect national comparative advantage.

With a proper call to action and support, as well as appropriate measures from the government for companies to embrace 4IR technologies, resources can be better allocated, and implementation plans can be more effective. Ostensibly, there has been mounting evidence in adoption studies that there is a robust positive and direct relationship between top management support and technology adoption studies (M. F. Ahmad et al., 2024; Aldossari et al., 2023; Bhattacharyya & Shah, 2022; Jayeola et al., 2022). Technology savvy top management grasps the potential return on investment through understanding which specific determinants are important to embark on digital transformation. With digital leadership, SMEs could appreciate the impact technological advancements would have on business performance (Radicic & Petković, 2023) and expedite its implementation. These SMEs can thrive, and nations can benefit from higher growth economy, higher productivity, better comparative advantages and provide better quality of life for the people.

This study will explore how drivers and barriers influence 4IR adoption by SMEs and the role of top management support. It will examine constructs in Diffusion of Innovation (DOI) theory and Technological-Organizational-Environmental (TOE)

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framework. The technological context comprises three core constructs, namely, relative advantage, complexity, and cost, reflecting the perceived benefits, implementation challenges, and financial implications of adopting new technologies. The organizational context includes top management support and firm size, emphasizing leadership commitment and resource capacity within the firm. Lastly, the environmental context encompasses government support and competitive pressure, representing external forces that influences 4IR technology adoption.

There has been limited empirical studies that assesses the mediating effect of top management support (Abu Hassan et al., 2023; Teh et al., 2024), as well as the strategy profiles within the context of 4IR technology adoption among Malaysian SMEs (Anwar et al., 2025), particularly through the lens of Miles and Snow's (1978) typology. In response to these gaps, this study not only investigates the direct relationships between TOE constructs and 4IR adoption but also examines the mediating effect of top management support within this framework. Additionally, it seeks to identify the strategy profiles of Malaysian SMEs in 4IR technology adoption. Profiling the SMEs' strategy typology could serve to explain the trends and enhance the understanding about 4IR adoption in the Malaysian context.

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1.3 Research Questions

Subsequent to the background and problem statements discussed above, this research will explicate how do determinants affect adoption of 4IR technologies among Malaysian SMEs. Thus, the researcher will test the statistical relationships among the variables towards answering the following research questions:

RQ1. To what extent do factors of adoption in the technological, organizational and environmental contexts affect 4IR technology adoption among SMEs?

RQ2. Does top management support mediate the relationships between factors in the technological, organizational and environmental contexts and 4IR technology adoption among SMEs?

RQ3. What is the strategy typology profile of Malaysian SMEs in relation to their adoption trend of 4IR technologies?

1.4 Research Objectives

This study aims to explore how key factors affect adoption of 4IR technologies by SMEs in Malaysia towards a successful digital transformation. As such, the specific aims of the study are:

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RO1. To investigate the relationship between technological context and 4IR technology adoption among SMEs.

RO1.1. To investigate the relationship between relative advantage and 4IR technology adoption among SMEs;

RO.1.2. To investigate the relationship between complexity and 4IR technology adoption among SMEs; and

RO.1.3. To investigate the relationship between cost of implementation and 4IR technology adoption among SMEs.

RO2. To analyze the relationship between organizational context and 4IR technology adoption among SMEs;

RO2.1. To analyze the relationship between top management support and 4IR technology adoption among SMEs; and,

RO2.2. To analyze the relationship between size of the firm and 4IR technology adoption among SMEs.

RO3. To examine the relationship between environmental context and 4IR technology adoption among SMEs.

RO3.1. To examine the relationship between competitive pressure and 4IR technology adoption among SMEs; and,

RO3.2. To examine the relationship between government support and 4IR technology adoption among SMEs.

RO4. To assess the mediating effect of top management support on the relationship between technological context and 4IR technology adoption among SMEs.

RO5. To assess the mediating effect of top management support on the relationship between organizational context and 4IR technology adoption among SMEs.

RO6. To assess the mediating effect of top management support on the relationship between environmental context and 4IR technology adoption among SMEs.

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RO7. To profile the strategy typology of the SMEs in Malaysia and the adoption trend of 4IR technologies.

1.5 Significance of Study

This study is conducted to contribute towards nation building by adding to the existing body of literature on the adoption of 4IR among SMEs. It will serve as a resource for academic researchers, industry practitioners, and government to understand the factors that promote adoption of the 4IR technologies from a firm-level perspective.

1.5.1 Theoretical Significance

A novel aspect of the study is in its choice of theories that are multidisciplinary in nature whereby it applies to information systems and information technology management, management and government fields. Consequently, combining these research theories will provide a more holistic approach in its findings and relevancy to the stakeholders. Extant studies on SME's strategic orientation have mostly been studied under entrepreneurship. This research, on the other hand, endeavors to study SME strategy under the field of strategic management, whereby 4IR technologies such as cloud computing as a viable and affordable course of action towards digital transformation. The proposed framework will incorporate top management support as mediator and the role it plays between technological, organizational and environmental contexts and the adoption of 4IR technologies.

1.5.2 Managerial Significance

As for the business community, 4IR is an opportunity for them to digitally transform a business. Innovations in 4IR via new combination between technology and market

will substantially enhance productivity (Lee et al., 2018). The study will contribute towards ensuring that SMEs will not be left behind and remain competitive globally. Previously, SMEs needed to grow big before they compete with the multinational companies (MNCs) and other big companies. Nonetheless with 4IR technologies, SMEs can harness its speed to gain agility as a competitive advantage against larger companies (Schwab, 2015). From a managerial standpoint, the study will shed light into the drivers of digital transformation. Hence, these managers will be able to allocate company time and resources optimally. SMEs that adopt 4IR technologies will stand at an advantage with lower costs, high-tech services and strong grasp of consumer habits. These companies can employ 4IR technologies to improve business processes and deliver better products, services, and experiences to their consumer and business clients (Fenech & Perkins, 2015; SME Corp. Malaysia & Huawei Technologies (M) Sdn. Bhd., 2018).

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For the government, the research can provide insights for policymakers and other stakeholders when implementing 4IR. With an effective, systematic and holistic 4IR technology adoption model for these SMEs, it will increase productivity and GDP growth; promote transformative innovation; and produce high-skilled jobs. The government will be better informed about where to allocate budget resources and provide incentives or grants where it is required or suited. Malaysia's aspirations to become a developed nation will be supported.

Moreover, countries around the world are banking on 4IR as a strategy to gain comparative advantage. SMEs are highly significant to world economy, with about fifty percent contribution to GDP, sixty percent in employment and ninety percent of

business enterprises worldwide (OECD, 2019a; World Bank Group, 2020). Thus, it is imperative that SMEs adopt 4IR technologies to remain relevant in the global value chain (OECD, 2019a). Many countries face similar challenges in transforming their SMEs with the dawn of 4IR. Therefore, the study's findings are useful and could apply to other economies, even developed ones. Case in point, according to the Business Population Estimates 2019 published by the Office for National Statistics of the United Kingdom (UK), in 2018 the UK has 99.9 percent SMEs, contributing to 60 percent employment and 52 percent of GDP. In the same vein, this research will focus on Malaysian SMEs (excluding micro-enterprises) in two major sectors, i.e. the manufacturing and service sectors, in their journey to realize a successful digital transformation by adopting 4IR technologies.

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1.6 Scope of the Study

1.6.1 Scope

This study focuses on factors that affect firm-level adoption of 4IR technologies by SMEs in the manufacturing and services sector as defined by the Department of Statistics of Malaysia (DOSM). It is contextualized in Malaysia; specifically, focusing only on small- and medium-sized enterprises as per the accepted definition by SME Corporation (SME Corp) as follows:

i. Manufacturing sector – annual sales turnover of between RM300,000 and RM50 million as well as employs between 5 and 200 full-time employees.
ii. Services sector – annual sales turnover of between RM300,000 and RM20 million as well as employs between 5 and 75 full-time employees.

This study has chosen organization as the unit of analysis. It targets SME decision-makers such as CEOs, MDs, and senior management. These individuals are essential because they oversee operations and make strategic decisions (Ghobakhloo et al., 2011), including crucial resource allocation for technology adoption (Fariborz Damanpour & Schneider, 2006). The study's data collection period was between February and August 2024.

In this study, the acronym for Fourth Industrial Revolution is 4IR, referencing Malaysia's National Fourth Industrial Revolution (4IR) Policy document. It covers all technologies under the policy, which includes artificial intelligence (AI), Internet of Things (IoT), blockchain, cloud computing and big data analytics (BDA), advanced material and technologies. These five technologies are the building blocks of myriads of other 4IR applications and technologies, particularly mobile applications services, e-commerce platforms. As such, the study also included 4IR technology adoption of any services, infrastructure, or platforms of 4IR technologies.

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1.6.2 Delimitations

This decision to exclude micro-enterprises was based on the following:

i. the overwhelming majority of the SMEs are micro-enterprises at 79 percent are excluded due to a lower survival rate, poor creditworthiness, financial management, and business viability (SME Corporation & World Bank Group, 2012); and,
ii. the micro-enterprises exist predominantly in the informal sector, which means they are not registered with the Companies Commission of Malaysia

(*Suruhanjaya Syarikat Malaysia* - SSM) (SME Corporation & World Bank Group, 2012) and hence, are excluded as this study's SMEs.

1.7 Operationalization of Key Terms:

In the absence of a globally accepted definitions used in the 4IR field and to maintain consistency, key terms are operationalized as follows in this study:

1.7.1 Adopter/non-adopters

These terms in the study refer to manufacturing and services sector SMEs that have adopted at least one of the technologies identified under the 4IR Policy, launched in 2021 by the Malaysian government. The 4IR technologies are advanced materials and technologies, AI, big data analytics (BDA), blockchain, IoT, cloud computing as well as other services, platforms, or infrastructure, including e-wallet, e-payment gateway, and the relevant infrastructure.

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1.7.2 Digital transformation

Organizations are aware that there is a need to digitally transform but many may become perplexed by the various terms such as digitization, digitalization, IT transformation, and computerization. Digital transformation is integrating digital technologies into all facets of business including business process, business model, market domain and the digitalizing of the whole organization. Simply put, digital transformation is integrating digital technologies into all facets of business (Beliveau et al., 2018). The transformation can be progressive, involving business processes such as customer management, human resources management, and supply chain

management (SME Corp. Malaysia & Huawei Technologies (M) Sdn. Bhd., 2018). In this study, digital transformation will also include e-business and digitalization.

1.7.3 Strategy Typology

A strategy categorization method that deals with how management handles engineering, administrative and entrepreneurial "problems" concurrently which will determine their typology. The four archetypes of strategy are defenders, analyzers, prospectors, and reactors.

1.8 Organization of the Thesis

The thesis contains several chapters, and this chapter serves to introduce the research and its contextual issues. Chapter Two comprises literature review relevant to the study, particularly on the concepts of 4IR, digital transformation by companies and the factors that promote adoption of 4IR technologies among SMEs. Subsequently in this chapter, an extensive review of literature on relevant theories is presented and a conceptual framework is formulated. In Chapter Three, the research methodology for the study is explicated and proposed hypotheses are tested. Next, Chapter Four discusses results from the tested hypotheses using SPSS Version 28 and SmartPLS 4.0. Finally, Chapter Five provides an explanation on the findings, draw conclusions, and make recommendations based on the outcomes of the whole research.

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CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of the chapter

In Chapter One, the need to study the issue of factors affecting 4IR technology adoption among SMEs and the impacts were highlighted. This chapter presents a literature review related to the investigation of 4IR technology adoption among SMEs. The focus of the review is adoption, whereby it will begin with a section on overview and definitions of SMEs as the research context; followed by a detailed literature review on national 4IR-related policies worldwide; economic contribution and challenges of Malaysian SMEs, SME landscape in Malaysia, the role top management support and strategy profile as companies transform. Subsequently, the underpinning theories related to technology adoption will be discussed, and finally, the chapter is concluded with the research framework and hypothesis development.

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2.2 Background of the study

The era of 4IR has introduced both opportunities and threats to all domains of industries globally; in a world that is already riddled with VUCA and currently facing health emergencies due to the COVID-19 pandemic. The new norm befallen us now is in the variations of social distancing practices that includes “forced” work-from-home and e-commerce services. All these challenges have now propelled companies to newfound motivation to adopt emerging and advanced technologies, particularly 4IR (Morgan, 2020; Pringle, 2020). These quick adaptation to the new norm disrupted by VUCA and the current pandemic was made possible due to a decade of the rise of the 4IR technologies, with emerging technologies such as AI, 3D printing, robotics

and affordable ones such as cloud computing and digital platforms (Bettiol et al., 2020). The impact of these emerging technologies are revolutionary particularly because they present new paradigms in business strategies that enhance efficiency product diversification (Junior et al., 2019; Moeuf et al., 2018), innovate business models (Savastano et al., 2019) such as mass customization (Conway, 2016; Weichert, 2017), as well as open up and reach new market opportunities such as e-commerce platforms (Y. Y. K. Chen et al., 2016).

Juxtaposing the disruption and risks posed by the 4IR era with the constraints SMEs face resource-wise, it is reasonable to think SMEs would be less willing to adopt 4IR technologies. According to a European Investment Bank (EIB) 2022/2023 report, advanced digital technology adoption rates are lower among smaller enterprises compared to larger enterprises. In 2022, only 30 percent of EU microenterprises implemented digitalization, compared with 65 percent of large firms (Brunori et al., 2023). Similarly in the case of Malaysia, most SMEs are still lagging behind large enterprises in terms of 4IR technology adoption (BERNAMA, 2025). Myriads of government intervention to provide a robust ecosystem, readiness assessment, and matching grants to SMEs, has failed to improve mediocre technology uptake (World Bank, 2020). Identifying the most effective drivers and eliminating barriers towards 4IR adoption by SMEs will be crucial to both private and public sectors to avoid these derailments in national economic development (BERNAMA, 2025).

On another note, while 4IR technologies have been proven to future-proof business, revolutionize industries and spur creation of new market opportunities, many companies refrained from implementing it (Pringle, 2020; Subramaniam, 2020; Tech

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Collective, 2020). Although Asian SMEs are aware that digitization is changing industries and markets, they lacked strategic focus, as evidenced by about 40 percent of respondents that have not defined their digital innovation strategy (Asian Productivity Organization (APO), 2019). According to a Firm-level Adoption of Technology study conducted by the World Bank Group (WBG) in 2022, SMEs cited competitive pressure as the top driver for adoption. Other reasons include access to new markets, and other firms adopted (Cirera et al., 2022). Similarly, across OECD nations, SMEs face challenges related to size; limiting their access to strategic resources, such as finance and talent (OECD, 2019).

Most decisions are made by the top management or the owner of the SME (Anwar et al., 2025). In a systematic literature review (SLR), top management support and size, have emerged as the most important organizational context studied (Zamani, 2022). Top management plays a strategic role to drive 4IR adoption based on relative advantages, overcome obstacles such as complexities, and ultimately gain higher financial gain, bigger markets and improve productivity (M. F. Ahmad et al., 2024; Aldossari et al., 2023; Bhattacharyya & Shah, 2022; Jayeola et al., 2022).It follows that top management sets the strategic direction, risk-taking levels, as well as resources allocation for implementation of digital transformation of an organization for employees and middle-managers. Without digital leadership, SMEs which are already limited in financial and other resources may not appreciate the impact technological advancements would have on business performance (Radicic & Petković, 2023) and derail its implementation. With the successful adoption of 4IR technologies, SMEs can thrive, and nations can benefit from higher growth in the economy. Malaysian

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SMEs' strategy archetype profiles could explain the trends in 4IR adoption in Malaysia,

2.3 National policies around the world

The rapid growth in the digital economy globally which was brought about by the 4IR technological advancements has prompted the formulation of 4IR-related national policies. These policies exhibit varying approaches as they revolve around mitigating prevailing national economic developmental issues, while simultaneously capitalizing on cutting-edge advancements to accelerate GDP growth by boosting productivity and gaining comparative advantage ahead of rival nations in the global market (Liao et al., 2018; Xu et al., 2018). It is also incumbent upon governments to address arising socio-economic issues such as greater skills gaps and workforce displacement attributable to automation, widening digital divide. Simultaneously, governments are tasked to provide necessary technology infrastructure, facilitate workforce upskilling, and provide funding and incentives to boost industrial transformation (Liao et al., 2018; Zervoudi, 2020). Further, these national policies often align and integrate with broader sustainability goals that focuses on green economics, in tandem with the United Nations Sustainable Development Goals (Mabkhot et al., 2021). There are also national policies that serve to balance between regulation and innovation for specific 4IR technology implementation, such as national AI policy, in the pursuit of national development (Hohman, 2025). The next section will discuss the national policies around the world related to 4IR technologies and compare the background of each country's call to action as well as the various approaches undertaken.

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2.3.1 National 4IR-related policies in Europe

Industrie 4.0 was first coined at the Hannover Messe in 2011 in Germany. Befittingly, it became the first country to introduce a national policy dedicated to 4IR with the launch of "High-Tech Strategy 2020" in 2012 and a strategic initiative called "*Industrie 4.0"* in 2013. This strategic initiative was designed to transform the manufacturing sector by fostering digitalization and integrating advanced manufacturing technologies (Liao et al., 2018). Since the German economy is heavily dependent on SMEs or *Mittelstand,* the policy places significant emphasis on facilitating their digital transformation. Towards this, *Industrie 4.0* focuses on enhancing SMEs' access to innovative and adaptable Industry 4.0 technologies, ensuring that these advancements are tailored to meet the specific needs of the *Mittelstand*, thereby strengthening their global competitiveness (Xu et al., 2018).

France followed suit in 2013 upon the launch of the French government initiative, "*La Nouvelle France Industrielle*." The impetus for this New Industrial France (NFI) program was to arrest the nation's decline in industrial competitiveness and ultimately, revive its industrial sector by focusing on emerging technologies and digital innovation. Moreover, the NFI program seeks to enhance the global competitiveness of French companies by fostering their transition toward future market demands. To ensure a more resilient and innovation-driven industrial development, the program also focuses on bridging the gap between traditional manufacturing and service industries through the integration of key technological solutions, including big data, cloud computing, robotics, and sustainable energy. In April 2015, Industry of the Future initiative was launched, then the following month NFI's second phase was launched and finally in July 2015, the industry of the Future Alliance was created

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(Ministry of the Economy, Finance and Industrial and Digital Sovereignty of France, 2016). In continuation of NFI industrial program, in 2021 a strategic roadmap called France 2030 mobilizes a huge €54-billion investment plan. The aim is fund researchers and emerging players among tech startups, and innovative SMEs to fuel innovation beyond its industrial policy to decarbonize the economy and transform strategic sectors i.e., digital technology, health, energy, and agriculture. To date, more than 3,500 projects worth approximately €30 billion has already been underway (Government of France, 2024).

2.3.2 National 4IR-related policies in Asia

As for the nations in Asia, two developed countries will be discussed, namely Japan and South Korea. Japan has developed comprehensive policies to navigate 4IR and build a super smart society through its Society 5.0 initiative (Holroyd, 2022). These policies aim to integrate advanced technologies into various sectors to address socio-economic challenges such as an aging population, labor shortages, and industrial competitiveness (Holroyd, 2022). Furthermore, Society 5.0 aims to balance economic development with social problem-solving, creating a human-centered society that integrates advanced technologies across various sectors, including healthcare, environment, and disaster management (Mavrodieva & Shaw, 2020).

South Korea is rapidly pursuing strategic 4IR policies with key initiatives and strategies to mitigate challenges involving regional disparities, workforce reskilling, and regulatory alignment. It began with The Presidential Committee on the Fourth Industrial Revolution (PCFIR), established in 2017, to spearhead 4IR national strategies and provides regulatory recommendations to foster technological integration

across industries (Chung & Chung, 2021; Liao et al., 2018). Complementing PCFIR, the Smart Factory Initiative 2018 aims to deploy 30,000 smart factories by 2025, and the Data, Network, AI (DNA) Initiative 2020 enhances AI research, 5G networks, and big data applications (Chung & Chung, 2021; Liao et al., 2018).. Meanwhile, the AI National Strategy (2019) envisions South Korea as a global AI leader by 2030, prioritizing R&D investments, workforce development, and regulatory advancements (Chung & Chung, 2021; Liao et al., 2018). The latest initiative vital to this transformation is the establishment of Center for the Fourth Industrial Revolution (C4IR) in collaboration with the World Economic Forum (WEF) 2024 (World Economic Forum, 2024). C4IR will formulate governance frameworks for 4IR by focusing on AI ethics, data security, and smart manufacturing.

For decades, China has served as a global manufacturing hub, primarily focusing on low-cost, labor-intensive production rather than high-value, innovation-driven industries (Agarwala & Chaudhary, 2019). Recognizing its vulnerabilities in high-tech manufacturing and its overreliance on foreign technologies, China has undertaken strategic initiatives to address these challenges (Nawaz et al., 2024). In response, the "Made in China 2025" policy was introduced in 2015, emphasizing technological self-sufficiency and targeting ten key strategic industries, including advanced information technology, robotics, aerospace, biopharmaceuticals, and new energy vehicles (J. Wang et al., 2020).

This policy is supported by government subsidies, tax incentives, and state-backed industrial funds aimed at fostering domestic enterprises in these crucial sectors (Nawaz et al., 2024). However, these measures have triggered trade tensions, particularly with

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Western countries, as the USA perceives this industrial strategy as a threat to its own high-tech industries, leading to tariff hikes and export restrictions (Branstetter & Li, 2022; Nawaz et al., 2024). Furthermore, the Chinese government has continued to invest heavily in subsidies and tax cuts to strengthen domestic innovation and industrial growth compared to the American government (Nawaz et al., 2024).

2.3.3 National 4IR-related policies in Malaysia

The first step in the Malaysian government's journey to digitally transform the country started with the establishment of the Multimedia Super Corridor (MSC) in 1996 (Figure 2-1). MSC is a high-technology business districts and special economic zone, to attract multinational corporations to invest in Malaysia (Economic Planning Unit Malaysia, 2021a). Malaysia Digital Economy Corporation (MDEC) was mandated to rollout MSC nationwide and accelerate MSC's evolution. Through this, seven flagship applications were initiated, including e-Government, Telemedicine, and the National Identity Card (MyKad) with a microchip. Henceforth, the 10th Malaysia Plan (2011-2015) incorporated a wide range of initiatives and policies to propel Malaysia into a developed nation through digital transformation. Fast forward to the 21st century, Malaysia has seen various achievements in terms of growth in knowledge-based economy to now, the digital economy. The strong commitment by the Malaysian government is evidenced by the launch of national policies (Figure 2-1) such as MyDIGITAL, Malaysia Digital Economy Blueprint and 4IR National Policy, resulting in myriads of initiatives to establish a conducive ecosystem for the economy (Economic Planning Unit Malaysia, 2021a).

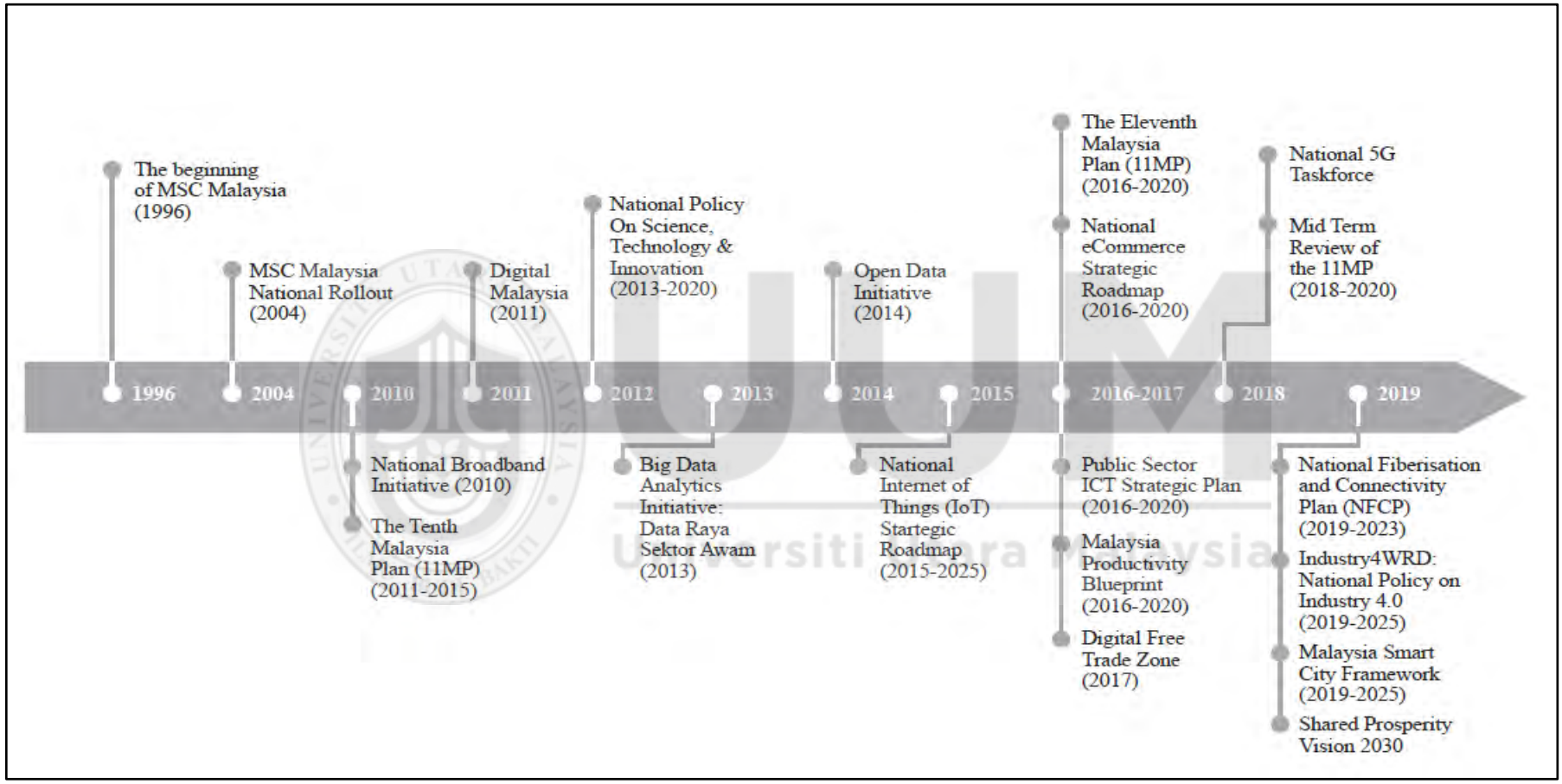


Figure 2-1
Policy evolution timeline in relation to ICT Development in Malaysia (1996-2019)
Source: Malaysia Digital Economy Blueprint (2021)

MyDIGITAL was launched on 19 February 2021, presenting a strategic, three-phase implementation rollout until the year 2030, aimed at significant expansion of the digital economy (Economic Planning Unit Malaysia, 2021a). The first phase of implementation identifying key initiatives to boost 4IR technology adoption in Malaysia, particularly among SMEs in adoption of e-commerce (Economic Planning Unit Malaysia, 2021a). In fact, MyDIGITAL targeted to achieve 22.6 percent of GDP (2018: 18.5 percent) and 875,000 SMEs adopting e-commerce. Given that the digital economy share to GDP has already reached 23 percent between 2021 and 2023, according to Malaysia Investment Development Authority (MIDA), the government has revised this target to 25.5 percent by end-2025 (Azhar, 2024).

Subsequently, the National 4IR Policy (Figure 2-3) was launched in July 2021 to provide an overarching strategic direction for the nation's socioeconomic transition, signaling the commitment of the Malaysian government towards whole-of-nation digital transformation post-pandemic era. The policy will be aligned with MyDIGITAL as well as the National Policy on Science, Technology and Innovation (DSTIN) 2021-2030 to propel Malaysia to become a high-tech nation by 2030 and ultimately, achieve developed country status (Figure 2-1). These policies will facilitate local technology development, thereby creating growth opportunities in the digital economy. Through four policy thrusts supported by 16 strategies and 32 national initiatives targeting businesses, society and the government. The four policy thrusts in the National 4IR Policy are to equip *rakyat* i.e. the workforce, with knowledge and skill sets required in 4IR, forge a connected nation via digital infrastructure development, regulations that are future-proof and agile with technological changes, and finally, accelerate technology innovation and adoption.

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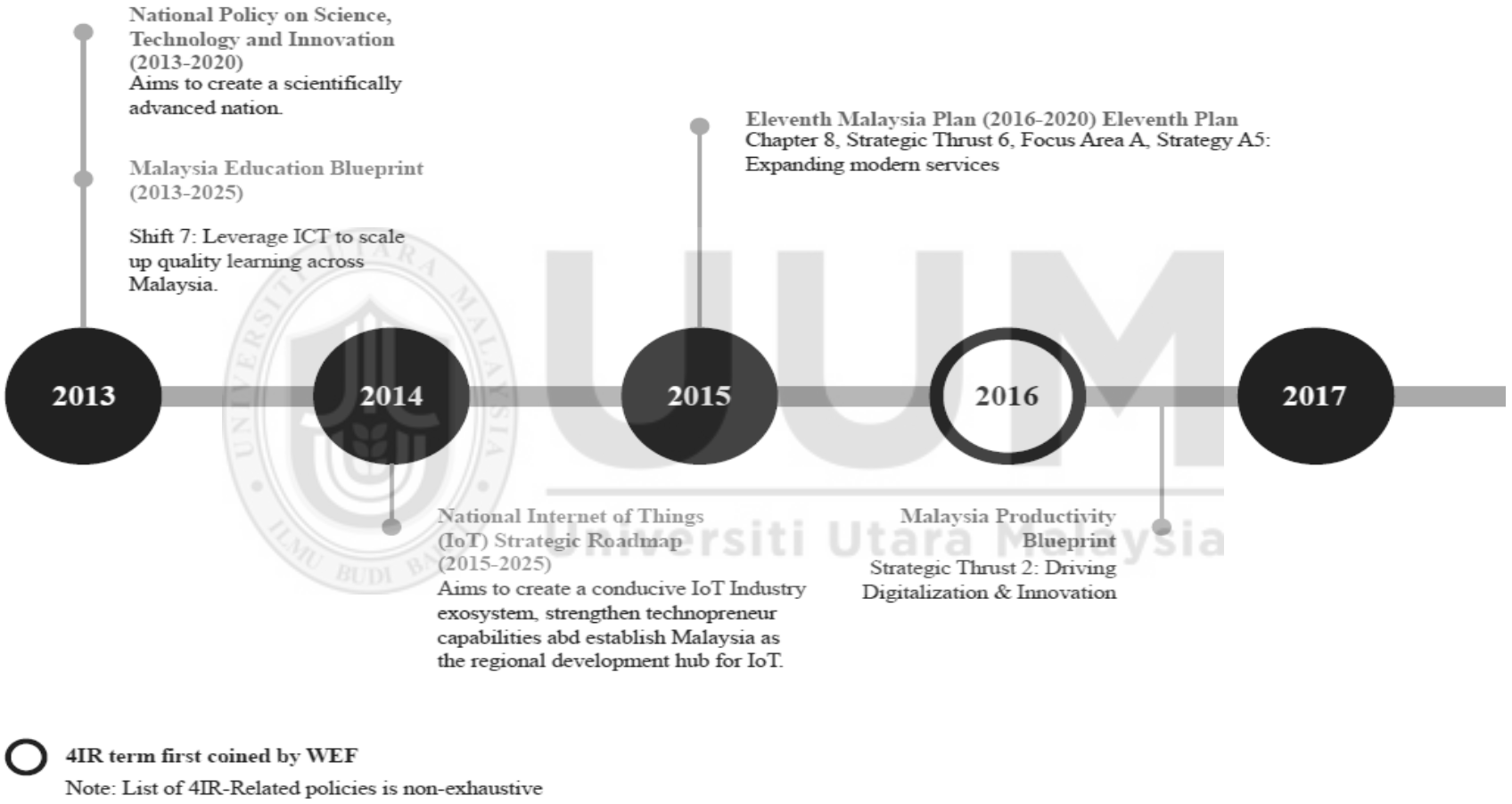


Figure 2-2
4IR-related policies in Malaysia. National 4IR Policy (2021)
Source: Malaysia Digital Economy Blueprint (2021)

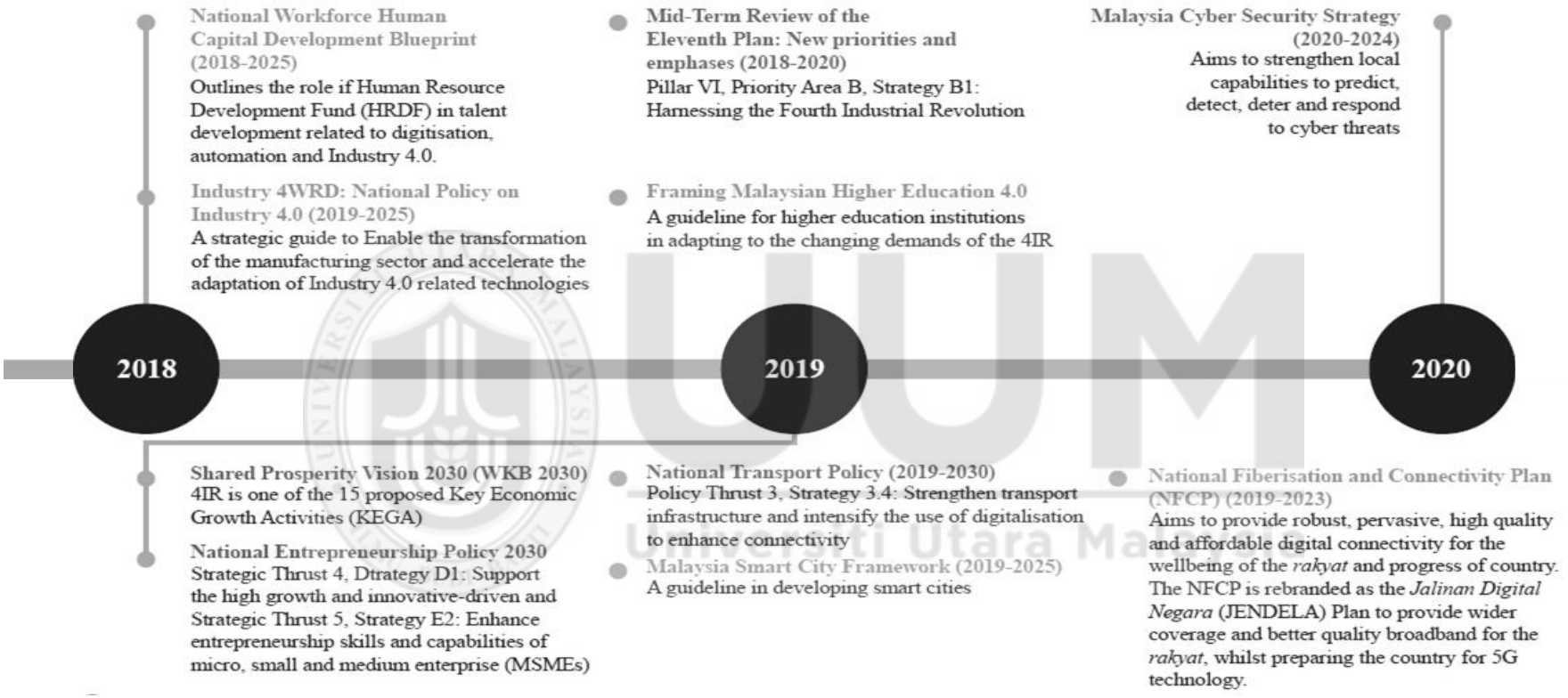


Figure 2-2 (continued)
4IR-related policies in Malaysia. National 4IR Policy (2021)
Source: Malaysia Digital Economy Blueprint (2021)

The four thrusts will be the subject focus in this study. It includes several strategies that specifies the government's role to facilitate local businesses' 4IR technology adoption (Strategy 13) by improving financial support given (Strategy 14) under thrust four. Across all thrusts, the Malaysian government stated strategies that revolve around government adoption of 4IR technologies, in terms of equipping the civil servants with upskilling and reskilling (Strategy 5), enhancing public digital structure (Strategy 8), and advocating agile regulatory approach, particularly those that hinder the development of 4IR technology adoption (Strategy 9 and 12). Strategy 16 is to prioritize using 4IR technologies in public sector service delivery, including in formulating policies and executing regulatory functions.

Following this, the National 4IR Policy (Figure 2-3) identified several key and supporting economic sectors based on GDP contribution and the potential to influence growth in other sectors. Altogether, the key focus economic sectors consist of eight industries from the services sector (such as healthcare and finance/insurance), as well as the manufacturing and agriculture macroeconomic sectors. Correspondingly, the supporting economic sectors cover four more industries from the services sector (such as ICT), as well as the construction and mining macroeconomic sectors. Notwithstanding that, the Policy forewarned that it has become an inevitability for businesses to adopt 4IR technologies to mitigate the pervasive disruption from the VUCA impact on the industry.

The policy document also identified five foundational 4IR technologies that would be the building blocks to a myriad of other 4IR applications and technologies towards developing the nation's technological capabilities. The technologies are artificial intelligence (AI), Internet of Things (IoT), blockchain, cloud computing and big data

analytics (BDA), advanced material and technologies. Initiatives under the first phase of implementation is already underway and has gone well into phase two and three. In phase one, the Policy aims to enhance the awareness and adoption of 4IR technologies through initiatives such as the National AI Framework, AI Park, and an annual AI & Big Data Week. Recognizing the importance of whole-of-nation approach and ensuring inclusivity, the National 4IR Policy established a national governance structure to oversee the implementation of all the initiatives across all ministries and agencies, as well as various stakeholder groups.

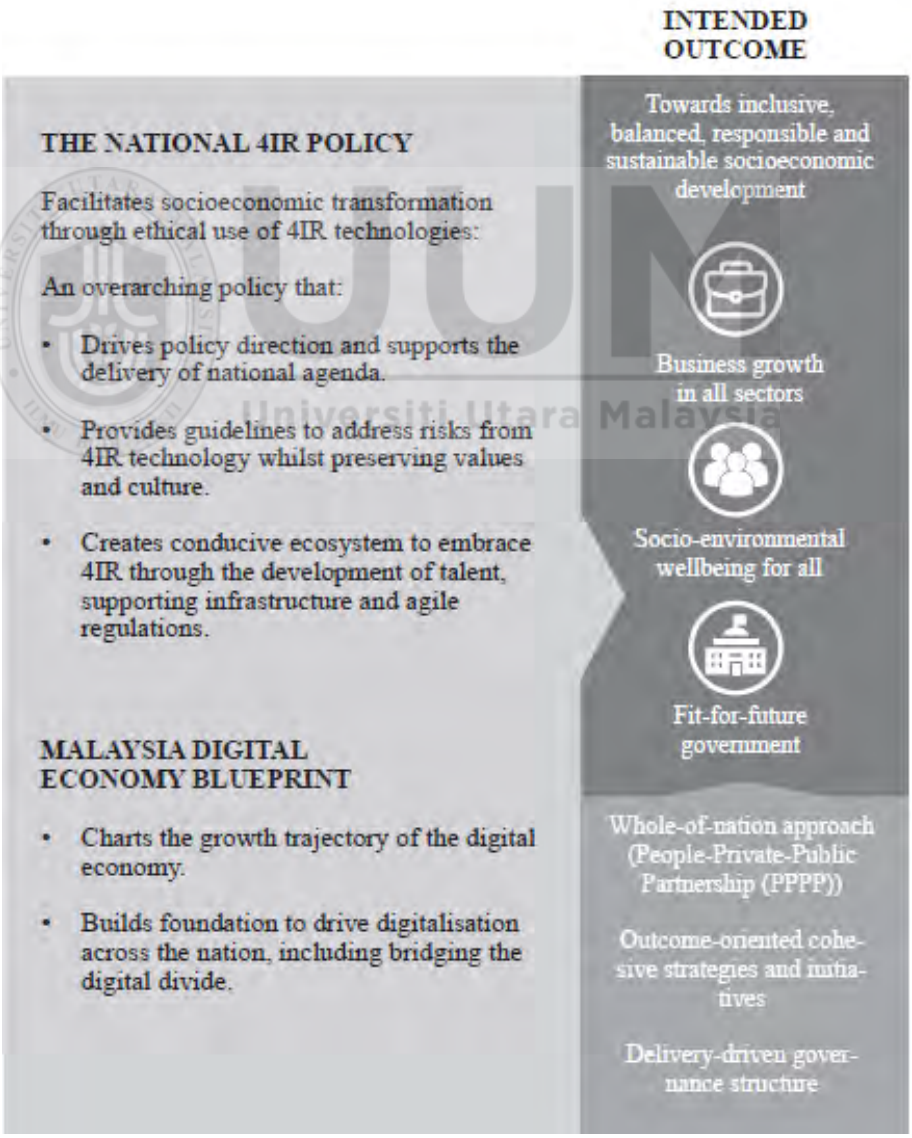


Figure 2-3
National 4IR Policy and Malaysia Digital Economy Blueprint
Source: Malaysia Digital Economy Blueprint (2021)

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Despite government efforts since the launch of the MSC in 1996, including incubators, accelerators, and funding (Appendix G and H) through various ministries and agencies (Kementerian Komunikasi Malaysia, 2024; Tham, 2023), 4IR technology adoption particularly among Malaysian SMEs remains low (Shahzad et al., 2023). This suggests that existing support mechanisms have not fully addressed key barriers such as costs, limited awareness of financing options, and insufficient digital capabilities among SMEs (SME Corp. Malaysia & Huawei Technologies (M) Sdn. Bhd., 2018; The World Bank, 2023). It is posited that outcome tracking is lacking, and fragmented coordination across programs and agencies further weakens efficacy of government support (Tham, 2023). This is supported by World Bank (2020) report citing 500 SME development programs between 2006 and 2010 overseen by 16 ministries and 60 agencies, with billions of ringgit spent to support SMEs.

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2.4 Contribution and Challenges Faced by SMEs Worldwide

In the context of the study, SMEs are of a special concern. Due to SMEs' sizable contribution to the economy and employment, nations are focused on their productivity and their role in the supply value chain (OECD, 2019a). SME comprises about 90 percent of business entities worldwide (World Bank Group, 2020). SME plays an integral role globally, with almost half of GDP contribution to the economy, and an average of 60 percent employment (OECD, 2019a; World Bank Group, 2020). Consequently, many studies in various fields have been focusing on SMEs' success and failures, particularly with the aim to identify factors that could improve their performance (Li et al., 2016). The change brought about by the digital era has brought about new opportunities, but has also rendered SMEs with additional challenges (Li et al., 2016; D. T. Matt & Rauch, 2020).

Generally, SME definitions differ across regions and countries, which inherently pose a comparison challenge to international statistics on SMEs. Each country's definition would qualify these SMEs for different types of incentives or funding, depending on its SME policy. Moreover, smaller nations generally set a lower thresholds compared to larger more advanced nations (OECD, 2019a). Nevertheless, the criteria used to determine whether an enterprise is an SME or a large company would normally be based on size of employment, annual sales turnover, and/or fixed assets (Awa et al., 2016b).

The SMEs are now aware that they need to adapt to changes brought about by 4IR but are struggling to remain relevant in the global value chain (OECD, 2019a). According to a study conducted by Asian Productivity Organization (2019), although Asian SMEs are aware that digitization is changing industries and markets, they lacked strategic focus, as evidenced by about 40 percent of respondents that have not defined their digital innovation strategy, thereby limiting their development and growth. The study also found that lack of management capabilities constrains SMEs' mid to long term development, and as digital transformation is led by CEOs, there is a gap in the whole of company's involvement to drive successful implementation. Digital transformation's benefits and barriers seem elusive, and without knowledge competencies, strategy formulation prove to be difficult (Erbay & Yıldırım, 2019).

It is challenging for SMEs to compete with the larger firms (Beliveau et al., 2018). Characteristics of this industrial revolution is its speed compared to previous three revolutions, which had taken decades to unfold (Schwab, 2015). Due to the disruptive nature of 4IR, SMEs could gain competitive advantage by adopting the 4IR

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technologies which enable them to be fast and agile. Nevertheless, despite all the opportunities presented in the market as well as the prospects of gaining competitive advantage, the problem is that SMEs are struggling to remain relevant in the global value chain (Müller et al., 2018). Moreover, given the importance of the SME contribution to the economy, the growth, competitiveness, and productivity of the SMEs have yet to rise significantly (OECD, 2019a).

SMEs generally face a similar situation whereby they face a double the challenge of having a pre-existing structure similar to larger, more established companies; but with limited resources similar to startups (Beliveau et al., 2018; Deshpande, 2019; Miskon et al., 2015). According to Andriole et al. (2018), digital transformation and emerging technology adoption are inseparable partners. SMEs who are supplying products and services to the industries that are undergoing digital transformation cannot afford to be complacent in terms of adopting these emerging technologies (Deshpande, 2019; Sharon, 2020; Tan, 2019). SMEs need to invest and adopt 4IR technologies to advance progressively through digital transformation.

Given this call to embark on digital transformation, it is imperative for SMEs to formulate strategies and more importantly, execute them (Abdullah et al., 2019; Chanias et al., 2019). Based on a 2015 report by MIT Sloan Management Review (Kane et al., 2015), nearly 90 percent of respondents indicated that business transformation is a directive of their digital strategies. Companies must think strategically in the long term (Schwab, 2017) and determine what business issues or challenges will be solved by the technology before making related investments (Marr, 2016; Marr & Brannan, 2020).

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2.5 SME Landscape in Malaysia

In Malaysia, the digitalization journey began in 1996 with the introduction of Multimedia Super Corridor (Economic Planning Unit Malaysia, 2021a). As a nation, Malaysia is a very strong contender in future readiness among economies worldwide, which indicated that the country has all the right conditions for digital success. According to IMD's World Digital Competitiveness Ranking (WDCR) 2024, Malaysia's rankings have progressively slipped in the past five years from 26th among 63 economies in 2020 to 36th among 67 economies in 2024. The report ranking shows the degree to which nations embrace and leverage digital technologies determines the transformation of governmental operations, business models, and broader societal structures. WDCR measures and ranks a nation's digital competitiveness via three categories, namely, knowledge, technology, and future readiness. Enhancing digital competitiveness requires a balanced integration of all three dimensions, which are foundational to innovation, inclusivity, and digital transformation in an economy (IMD World Competitiveness Center, 2024). In response to the WDCR 2024 report, the Malaysian government and several agencies underscored various national policies already underway post-pandemic, such as the National Artificial Intelligence Roadmap, National Blockchain Roadmap and National Internet of Things (IoT) Strategic Roadmap, that are all aligned with the Malaysia Digital Economy Blueprint (Fadzil, 2025).

2.5.1 Malaysian SME Economic Sector Contribution

In another report entitled Malaysia's Experience with the SME Masterplan – Lessons Learned, the World Bank identified SMEs to be a critical component towards Malaysia becoming a high-income economy (World Bank Group, 2020). According to DOSM,

in 2023 there are 1,101,725 (2015: 907,065) SMEs, representing 96.9 percent of business establishments in Malaysia across all macroeconomic sectors (Department of Statistics Malaysia, 2024c). Between 2019 and 2023, although Malaysian SMEs experienced a cumulative average growth rate (CAGR) of 2.5 percent annually in the number of establishments, their overall share declined to 96.9 percent—marking the lowest proportion during the period, in contrast to the peak of 98.5 percent recorded in 2019 pre-pandemic COVID19.

Table 2-1
Breakdown of SMEs in Malaysia by size and sector

SECTOR	Number of SME Establishments (Reference Year 2022)				Share of SMEs (%)	Large Firms	Overall Establishments
	Micro	Small	Medium	Total SMEs			
Services	737,221	184,128	15,444	936,793	87.56	15,069	951,862
Manufacturing	21,970	27,162	2,349	51,481	4.81	3,024	54,505
Construction	39,187	26,283	3,545	69,015	6.45	2,047	71,062
Agriculture	5,246	5,128	998	11,372	1.06	1,626	12,998
Mining & Quarrying	78	673	419	1,170	0.11	270	1,440
TOTAL	**803,702**	**243,374**	**22,755**	**1,069,831**	**100**	**22,036**	**1,091,867**

Source: Economic Census 2023 – Profile of Micro, Small and Medium Enterprises, DOSM

Table 2-1 provides a breakdown of SMEs in Malaysia by size and sector. The next section discusses the performance of the SMEs, focusing on the manufacturing and services macroeconomic sectors as these two sectors are very important to the Malaysian economy. The definition of manufacturing used in this study follows DOSM's current Malaysia Standard Industrial Classification (MSIC) 2008 Ver. 1.0: "Manufacturing, includes the physical or chemical transformation of materials, substances, or components into new products, although this cannot be used as the single universal criterion for defining manufacturing (see remark on processing of

waste below). The materials, substances, or components transformed are raw materials that are products of agriculture, forestry, fishing, mining or quarrying as well as products of other manufacturing activities. Substantial alteration, renovation or reconstruction of goods is generally considered to be manufacturing."

Meanwhile, the service sector, also known as the tertiary sector, is defined as "This section includes wholesale and retail sale (i.e. sale without transformation) of any type of goods, and rendering services incidental to the sale of merchandise. Wholesaling and retailing are the final steps in the distribution of merchandise. Also included in this section are the repair of motor vehicles and motorcycles. This section also includes wholesale and retail trade and repair of motor vehicles and motorcycles; wholesale trade, except of motor vehicles and motorcycles; retail trade, except of motor vehicles and motorcycles". Services categorization are subsectors as follows: wholesale and retail; repair of motor vehicles and motorcycles; accommodation and food service activities; information and communication (ICT); transportation & storage; human health and social work activities, education; arts, entertainment & recreation; professional, scientific and technical activities, financial and insurance/takaful; and finally, real estate activities (Department of Statistics Malaysia, 2008).

It is notable that SMEs surpassed all aspects of its contribution to GDP growth, value-added amount and percentage contributions to national GDP, as well as employment. In 2023, the SMEs GDP growth rate was at 5.0 percent, which exceeded Malaysia's and non-SMEs' GDP growths at 3.6 percent and 2.7 percent, respectively (Department of Statistics Malaysia, 2024c). SMEs contributed 39.1 percent to national GDP in 2023 (2022: 38.6 percent) with value-added worths RM613.1 billion (2022: 584.1 billion).

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These contributions to GDP were driven by services and manufacturing sectors, which constituted a sizable 84.8 percent of the total SME GDP and 82.6 percent share of national GDP (Department of Statistics Malaysia, 2024c).

As for exports performance, in 2023, SMEs recorded RM152.2 billion, which is 12.2 percent of total exports at a year-on-year (y-o-y) growth rate of 4.5 percent, lower than y-o-y 17.2 percent in 2022 (Department of Statistics Malaysia, 2024c). It was severely affected by the manufacturing sector severely contracting at -0.7 percent compared to 19.5 percent in 2022, but corresponded with global trend due to lower commodity prices such as LNG, crude palm oil and crude petroleum, as well as geopolitical uncertainties (Malaysia External Trade Development Corporation (MATRADE), 2023). Top three exports markets are consistent with the nation's biggest trade partners, namely, Singapore, China, and the United States. Nevertheless, the SME services sector grew considerably at 24.2 percent in 2023, almost tripling 2022 rate at 8.8 percent (Department of Statistics Malaysia, 2024c). In terms of value of exports, the manufacturing sector continues to dominate SME exports at RM113.8 billion, constituting 74.3 percent of SME exports share. Meanwhile, the SME services sector contributes RM35.4 billion (2022: RM28.5 billion) of SME exports share (Department of Statistics Malaysia, 2024c).

Finally, the national share of SMEs employment stood at 48.5 percent in 2023 (2022: 48.2 percent) with y-o-y rate of 3.5 percent (2022: 3.8 percent), recording the highest employment growth rate against Malaysia's and non-SME employment rates at 2.8 and 2.1 percent since 2021, respectively (Department of Statistics Malaysia, 2024c). The number of persons engaged by SMEs was 7.86 million (2022: 7.59 million)

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persons from a total of 16.20 million persons nationwide and 8.34 million persons for non-SMEs. Once again, the manufacturing (at 16.3 percent) and services (at 64.7 percent) emerged as the top two sectors making up 81 percent share of SME employment, with (Department of Statistics Malaysia, 2024c). In terms of labor productivity, all five SME economic sectors recorded an increase of between 4.9 to 1.4 percent except for the manufacturing sector, which posted -0.9 percent (2022: 2.9 percent) in 2023 (Department of Statistics Malaysia, 2024c).

2.5.2 Challenges Faced by Malaysian SMEs

Malaysia's experience with the SME Masterplan 2012–2020 reflects the critical role of SMEs in economic growth and employment. However, Malaysian SMEs continue to lag behind their counterparts in other developing economies in terms of GDP contribution and export performance. For instance, in 2010, the Malaysian SMEs' GDP contribution was at 32 percent and only 16 percent of total exports, which was about 20 percent lower compared to SMEs in developing economies such as the Philippines, Taiwan, Hong Kong (SME Corporation & World Bank Group, 2012). Despite progress in both indicators, the Masterplan fell short of its 2020 targets, highlighting persistent structural and strategic gaps in the SME landscape. Thus, the government's concern is warranted given the percentage of SMEs involved in the economy (SME Corp. Malaysia & Huawei Technologies (M) Sdn. Bhd., 2018).

In the context of 4IR technology adoption, the biggest obstacle is the perceived high costs involved in digital transformation, coupled with limited awareness regarding available financing options (SME Corp. Malaysia & Huawei Technologies (M) Sdn. Bhd., 2018; The World Bank, 2023). Another hurdle is the lack of digital skills which

was also being addressed in MyDIGITAL to boost adoption of e-commerce among SMEs. The lack of digital skills will undermine the perceived benefits of adoption of 4IR technologies and further reinforces SMEs' impaired perception of high cost outlay with uncertainties in obtaining return on investment (The World Bank, 2023). Moreover, inadequate digital skills would also impair leveraging on 4IR technologies in building suitable digital business strategies (SME Corp. Malaysia & Huawei Technologies (M) Sdn. Bhd., 2018). Although the government has introduced funding, grants, and upskilling programs to boost SMEs digital transformation, adoption remains sluggish (BERNAMA, 2025).

Critically, another skill that is often overlooked is the digital management skills among SMEs' top management in dealing with these challenges. Although existing studies consistently emphasize the critical role of top management in facilitating technology adoption (Aldossari et al., 2023; Zhou & Zheng, 2023), a persistent gap remains. As key decision-makers, top executives are responsible for resource allocation (Abdul Rasheed & Nafiz, 2022; Lin, 2014) as well as influence organizational readiness and employee acceptance (Hassan et al., 2023). Consequently, even when SMEs are poised to adopt technologies, top management's lack of support can significantly hinder successful digital transformation (Ammeran et al., 2023; Veeraya et al., 2024).

The low rate of 4IR technology adoption among Malaysian SMEs may reflect deeper underlying challenges beyond just technological or financial barriers. These SMEs often adopt digital technologies in response to short-term pressures, rather than as part of a proper strategy. This also signifies deficient management skills, where SMEs react on an ad hoc basis to ensure survival rather than follow clear long-term plans

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(Ammeran et al., 2023; Veeraya et al., 2024). As a result, these SMEs may not fully commit to digitalization, even with external support. In conclusion, despite an abundance of government interventions, these management issues continue to hinder 4IR technology adoption by SMEs (World Bank, 2020).

In terms of economic challenges, based on the most recent DOSM reports, Micro, Small and Medium Enterprises, 2023 as well as the Economic Census 2023 – Profile of Micro, Small and Medium Enterprises, the manufacturing sector has not returned to pre-pandemic performance in 2019 due to geopolitical instability causing higher inflationary pressures and lower commodity prices. The recent tariff announcements on imported goods by the USA has exacerbated these issues in terms of trade (Ikram & Hazim, 2025; Zakri, 2025), although it is not uniquely affecting the SMEs. Nevertheless, the aftermath of tariffs would mean higher cost of doing business for SMEs which are already constrained by limited financial resources (Zakri, 2025). Therefore, the government has stepped up efforts to ensure that SMEs are supported in their digital transformation by implementation of policy initiatives discussed in section 2.3.3 National 4IR-related policies in Malaysia.

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2.6 Conceptual Definition of Key Terms

The following are the conceptual definitions of key terms and constructs.

2.6.1 Adoption of 4IR technologies

4IR can be described as the advent of "cyber-physical systems" involving entirely new capabilities for people and machines (Liu & Xu, 2017; Schwab, 2017), an integration among biological, physical and digital systems (Drath & Horch, 2014). As explained

by Liu & Xu (2017), these technologies possess smart, communicating and hyperconnected systems. Another study's brainstorming session among 11 multinational scholars deliberated the definition of 4IR that includes Second Information Technology (IT) revolution; major technological disruptions with digitalization: digital age with IoT or Industrial Internet; IoT revolution; Super Disruptive Innovation (Lee et al., 2018).

Research on technology adoption has been studied in the past three decades, mainly in the USA, followed by the developed countries and it has since gained momentum among the developing countries in the current decade (Parnell et al., 2015). Adoption refers to "the stage in which a technology is selected for use by an individual or an organization" (Carr, 1999). The terms 'technology' and 'innovation' adoption will be used interchangeably in this study (Rogers, 1995; Tornatzky & Fleischer, 1990).

In his earlier work on the process of innovation adoption, Damanpour (1991) posited that there are two phases involved: initiation and implementation. He also included technology adoption as one of the definitions of innovation at organizational level. "Adoption is a subtle concept, which must be used carefully if we are to understand the innovation process" (L. G. Tornatzky & Fleischer, 1990). The concept of adoption is non-linear, sometimes in loops; and cannot be identified at a single point of time, and thus, commonly characterized by using a stages model (L. G. Tornatzky & Fleischer, 1990).

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2.6.2 Relative Advantage

Relative advantage, a key construct within the innovation diffusion and technology adoption frameworks, refers to the degree to which an innovation is perceived as superior to the idea or technology it replaces (Rogers, 2003). This factor can manifest in various forms such as increased economic profitability, enhanced efficiency, operational convenience, or improved social standing (Moore & Benbasat, 1991). In the context of technology adoption, particularly for SMEs, relative advantage captures the perceived benefits that an innovation brings to an organization, motivating companies to prioritize adoption (Tornatzky & Klein, 1982). Examples of relative advantage from any of the adopted 4IR technologies could be higher productivity, better quality of work, help gain cost savings, improved customer service, and even create opportunities for market expansions or new product/service offerings.

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Prior studies have consistently underscored that SMEs are more likely to adopt digital technologies, such as cloud computing, AI, and IoT, when they believe these technologies will improve productivity, reduce operational costs, and provide competitive differentiation (Ahmad et al., 2015; Alshamaila et al., 2013; Garg & Choeu, 2015; Kumar et al., 2017; Maroufkhani et al., 2020; Usman et al., 2019).

The relative advantage construct in the 4IR context thus encapsulates both economic and technological dimensions of perceived value. For instance, 4IR technologies such as AI-driven e-commerce platforms can enhance real-time tracking of inventories and offer improved after-sales services (Mensah et al., 2021; Mohd Isa & Alenezi, 2022). Such perceptions of advantage shape the adoption decision-making of SMEs, acting

as a pivotal factor in overcoming barriers to innovation (Park & Kim, 2019; Pathan et al., 2017; Safari et al., 2015).

2.6.3 Complexity

Complexity is a critical factor in technology adoption studies, representing the perceived difficulty or effort associated with understanding and using an innovation (Rogers, 2003). Within TOE framework, complexity refers to the extent to which an innovation is seen as relatively challenging to comprehend and implement compared to existing processes (Tornatzky & Klein, 1982). This perception of complexity encompasses both technical challenges—such as system integration and required skills—and the cognitive or organizational hurdles associated with a new technology (Venkatesh et al., 2003). In other words, complexity is the extent to which 4IR technologies adopted are regarded as being relatively difficult to understand and use by employees, require new skills to the company, and pose significant obstacles to being integrated into existing work processes.

In terms of 4IR technologies, complexity is particularly relevant as SMEs often lack the necessary technical expertise, financial resources, or digital maturity (Ghobakhloo et al., 2011; Maroufkhani et al., 2020). Empirical studies have consistently shown that when 4IR technologies—such as artificial intelligence (AI), cloud computing, and Internet of Things (IoT) – are perceived as overly complex, adoption rates among SMEs decline (Al-Qirim, 2007; Mirchandani & Motwani, 2001). This negative relationship underscores that complexity acts as a barrier to adoption, deterring firms from leveraging the competitive advantages offered by these technologies.

2.6.4 Cost

Cost is widely recognized as a significant determinant in technology adoption, representing the perceived financial burden associated with acquiring, implementing, and maintaining a new innovation (Tornatzky & Klein, 1982). In the context of the TOE framework and 4IR technology adoption among SMEs, cost encompasses not only direct monetary expenses—such as purchasing hardware, software, and infrastructure—but also indirect costs, including training, process changes, and potential disruptions during implementation (Ghobakhloo et al., 2011).

The perception of cost as a barrier is particularly pronounced in SMEs, which often operate under tight financial constraints and limited access to capital (Al-Qirim, 2007). Numerous empirical studies have shown that high perceived costs can inhibit technology adoption in SMEs, as they prioritize immediate cost savings and risk aversion over long-term strategic gains (Mirchandani & Motwani, 2001; Maroufkhani et al., 2020). However, the relationship between cost and adoption is not always straightforward; contextual factors, such as government incentives and industry-specific conditions, can mediate the negative influence of perceived costs (Usman et al., 2019).

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2.6.5 Firm Size

Globally, there is not a single universally accepted definition of an SME. Extant literature review is reveals various definitions used in various regions and countries (Sidek et al., 2020). The European Commission defines SMEs as, “The category of micro, small, and medium enterprises is made up of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding EUR 50 million,

and/or an annual balance sheet total not exceeding EUR 43 million." (European Commision, 2017).

The USA on the other hand, have a myriad of definitions of a small business, varying from industry to industry, agency to agency. Each will specify definitions of company size along two main criteria, i.e. average number of employment and/or average annual receipts. Case in point, the U.S. Small Business Administration publishes a table to determine if an entity qualifies as a small business and that there are currently 99.9 percent small businesses in America. Meanwhile, the U.S. Census Bureau labels small businesses as those having 500 or fewer employees, but the U.S. Healthcare agency defines a small business if an enterprise employs 50 or less employees.

In China, the definition of SME is just as complex but based SME Promotion Law of China with criteria of employment, types of industries, and revenue/total assets (Sidek et al., 2020). Perhaps since China has a large population, the SME sizes are much larger in terms of number of employees, i.e. less than 2,000 employees for manufacturing sector, whereas 200 to 800 employees for a service sector (Sidek et al., 2020). Additionally, Japan defines SME based on the amount of capital or the number of employees according to industry sector as defined by the Small- and Medium-sized Enterprise Basic Act 1999 (Clavecilla, 2023). Nevertheless, in general, the criteria used to classify an SME would usually be a combination of size of employment, yearly sales turnover, at times, fixed assets (Awa et al., 2016b).

This study will adopt SME Corporation Malaysia's revised and adopted SME definition for small and medium enterprises (excluding microenterprises). The definition found in Table 2.2 was endorsed by NSDC in 2013 and is applicable for all

SME establishments in all five macroeconomic sectors in Malaysia. The current definition also applies only to entities that are registered with *Suruhanjaya Syarikat Malaysia* (Companies Commission of Malaysia or SSM) and exclude those entities that are public-listed on the main board, and subsidiaries of public-listed companies on the main board; multinational corporations; government-linked companies; and Minister of Finance Incorporated Companies, as well as state-owned companies.

Table 2-2
Definition of Malaysian SMEs

Sector	SMEs Size	Annual Turnover	Number of Full-Time Employees
Manufacturing	Micro	Less than RM300,000	Less than 5 employees
	Small	Between RM300,000 to less than RM15 million	From 5 to less than 75 employees
	Medium	Between RM15 million to not exceeding RM50 million	From 75 to not exceeding 200 employees
Agriculture, Mining and Quarrying, Construction and Services	Micro	Less than RM300,000	Less than 5 employees
	Small	Between RM300,000 to less than RM3 million	From 5 to less than 30 employees
	Medium	Between RM3 million to not exceeding RM20 million	From 30 to not exceeding 75 employees

Source: DOSM Economic Census, 2023

2.6.6 Top Management Support

An organization's ability to embark on the adoption of new technologies depends heavily on its internal characteristics and available resources. When discussing the process of adoption, Damanpour & Schneider (2006) concluded that this phase entails top management's decision to adopt and allocate resources. Top management support is one of the organizational factors in the TOE framework by Tornatzky and Fleischer

(1990). Top management support is the extent to which top executives comprehend and embrace technological capabilities of a new technology (Maroufkhani, Tseng, et al., 2020). Within the organizational context of the TOE framework, top management support consistently emerges as a critical determinant of successful technology adoption and implementation (Alshamaila et al., 2013; Zakari Usman et al., 2019).

Strong support from top management is a crucial factor in whether a company adopts Industry 4.0 (IR4.0) technologies in initiating and deciding the adoption of any technology and innovation (AlBar & Hoque, 2019; Trevor Clohessy & Acton, 2019; Mohtaramzadeh et al., 2018). When top management fully grasps the strategic advantages of adopting these advanced technologies, it significantly boosts the organization's ability to develop and leverage high-tech competencies (Shahzad et al., 2023). Top management support also involves the willingness of the top management to invest funds and take risks in adopting 4IR technologies. It is about the likelihood and motivation of the top management to gain competitive advantage, as well as prioritizing 4IR technology adoption as vital strategically (Maroufkhani et al., 2023).

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2.6.7 Competitive Pressure

Competitive pressure, an environmental factor, significantly drives SME adoption of 4IR technologies (Maroufkhani et al., 2023). Competitive pressure refers to an organization’s degree of force from its competitors (Iacovou et al., 1995). Aside from rivalry among competitors, it also includes the intensity of pressure from various parties in the industry for the SME to adopt 4IR technologies (Maroufkhani et al., 2023). Increased competitive pressure pushes for 4IR technology adoption, as businesses seek to maintain competitive advantage amidst market turbulence, and

shorter product life cycle (Ghobakhloo et al., 2022). Furthermore, SMEs supplying larger firms risk obsolescence and market loss to rivals if they fail to adopt IR4.0 technologies (Shahzad et al., 2023).

2.6.8 Government Support

Government support, an environmental context in TOE framework, is crucial for technology adoption by SMEs (Abu Bakar et al., 2020). Recent literature further emphasizes this, highlighting various forms of government intervention that facilitate such adoption. For instance, studies found that government policies and subsidies are critical in encouraging sustainable technology adoption among Malaysian SMEs (Abu Bakar et al., 2020). Additionally, research on emerging economies underscores that government support, through measures like financial assistance and regulatory frameworks, significantly influences SMEs' digital transformation and their ability to leverage advanced technologies (Sharma et al., 2024). This support helps overcome barriers such as financial constraints and limited absorptive capacity, thereby enhancing SME competitiveness and fostering innovation (Abu Bakar et al., 2020). Government support is an exceptionally essential determinant in technology adoption in most developing countries. For example, Malaysia and China have formulated national policies related to 4IR technologies and heavily invested in providing financial assistance. These policies will facilitate local technology development, thereby creating growth opportunities in the digital economy (Economic Planning Unit Malaysia, 2021a; Nawaz et al., 2024).

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2.7 Underpinning Theories

This section is a critical review of literature on theories related to the topic of the thesis. It is meant to act as a base for the experimental analytical section of the thesis. Literature selected must be related to the research as a base to guide the development of research framework after an extensive exercise was conducted to consider (and ruled out) various adoption theories such as Theory of Reasoned Action (TRA) by Fishbein and Ajzen (1975), Theory of Planned Behavior (TPB) by Ajzen (1991), Technology Acceptance Model (TAM) by Davis (1989), extended models of TAM such as UTAUT by Venkatesh in 2003, Institutional theory, and due to the disruptive nature of 4IR – the theory of disruptive innovation.

Extant literature reviewed has not revealed any consensus on a specific theory for technology adoption. Typical theories used to understand technology adoption process include theory of reasoned action (TRA) (Fishbein & Ajzen, 1975); theory of planned behavior (TPB) (Ajzen, 1991); technology acceptance model (TAM) (Davis, 1989; Davis et al., 1989); unified theory of acceptance and use of technology (UTAUT) (Venkatesh et al., 2003); Diffusion of innovation theory (DOI) (Rogers, 1995); the technology-organization-environment (TOE) framework (L. G. Tornatzky & Fleischer, 1990), Technology Readiness Index (Parasuraman, 2000) and Perceived E-Readiness Model (Molla & Licker, 2005) and institutional theory (INT) (DiMaggio & Powell, 1983, 1991).

As for theories to study the adoption factors at organizational level, review of literature indicates that in the more recent studies, DOI theory, TOE framework and institutional theory are overwhelmingly used as underpinning theories (Molinillo & Japutra, 2017;

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Oliveira & Martins, 2011; Salahshour Rad et al., 2018). This research will explicate DOI and TOE theories and integrate the profile of Malaysian SMEs with Miles and Snow's strategy typology model (1978) in order to better explain 4IR technology adoption. The following are underpinning theories used in the research.

2.7.1 Diffusion of Innovation (DOI) Theory

DOI (Rogers, 1995) is a theory of how, why, and at what rate new ideas and technology spread through cultures, operating at the individual and firm-level. DOI theory sees innovations as being communicated through certain channels overtime and within a particular social system (Rogers, 1995). The theory was introduced by Everett Rogers in 1962 after observing farmers in his home community who refused to adopt agricultural innovations. In his book, Rogers (1995) defined innovation as an idea, practice, or object, perceived to be new by the adoption unit through a special type of communication through identified influencing factors of adoption. As per Figure 2-4, individual (leader) characteristics, internal characteristics of organizational structure, and external characteristics of the organization are important to organizational innovativeness (Rogers, 1995). It has been applied to individuals and organizational units of analysis.

There are a number of innovation attributes discussed by Rogers 1995 that are crucial to determine technology or innovation adoption:

i. Relative advantage is "the degree to which an innovation is perceived as being better than the idea it supersedes" (Rogers, 1995). In his book, Rogers (1995) referred to economic profitability as the expression of relative advantage. The

relationship between relative advantage and innovation diffusion and usage is a positive one.

ii. Compatibility, defined as "the degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters" (Rogers, 1995). It means that an innovation that fits more closely with an adopter's current situation would have a positive effect on the rate of adoption and usage of the new technology.

iii. Complexity relates to the "degree to which an innovation is perceived as being difficult to use" (Rogers, 1995). It simply means that a technology which is easier to use and requires less effort to be incorporated in the existing systems or processes will be adopted faster compared to one that involves acquisition of new skills or understanding of new ideas. This attribute is assumed to have a negative impact on the rate of adoption and usage of the new technology.

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iv. Observability means the extent to which the results of an innovation is visible to others (Rogers, 1995). For this attribute, there would be a positive influence on the rate of adoption and usage of the new technology.

v. Trialability is the final attribute; referring to the idea that if a potential adopter can try out a new technology in their own context and situation satisfactorily, it would dispel much of the uncertainties. Thus, a positive relationship is assumed between trialability and the rate of adoption and usage of the new technology.

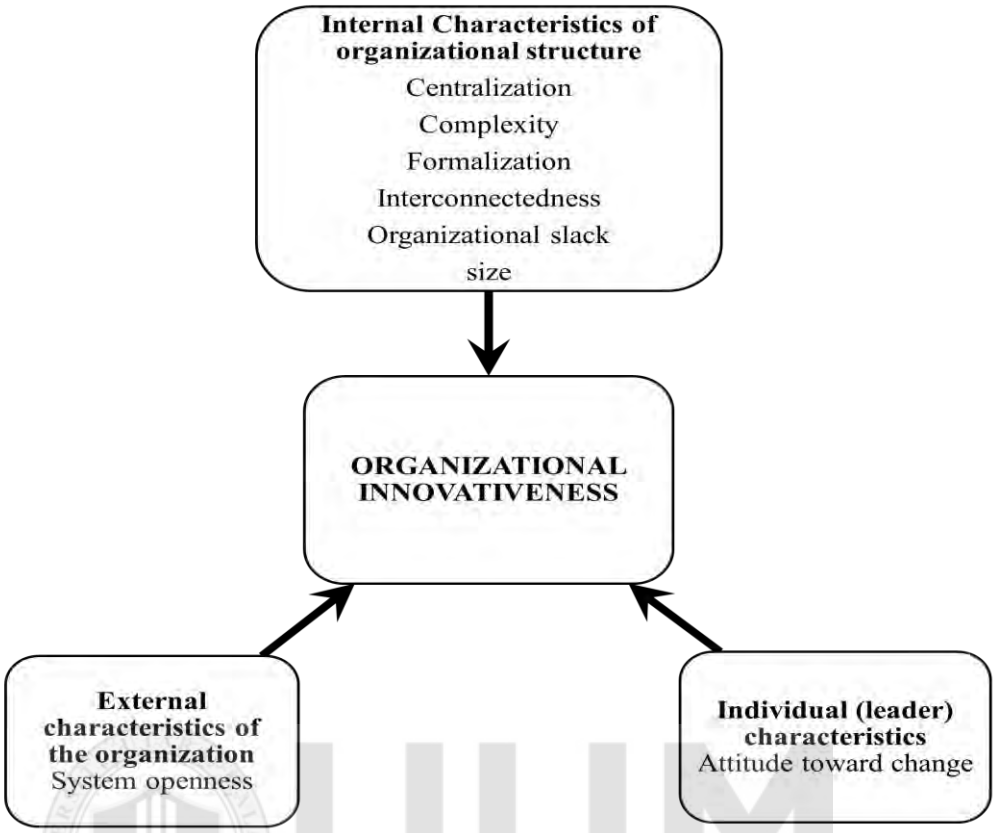


Figure 2-4
Diffusion of innovation theory (Rogers, 1995)

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Another aspect the DOI theory is famous for is exhibited in Figure 2-5 showing a bell curve with five personality traits of innovativeness: innovators, early adopters, early majority, late majority, laggards. The bell curve shows the expected percentage of market share against the sequence by which each personality trait would accept the product, beginning with the innovator group and lastly, the laggards (Roger, 1995). Thus, it can be used to formulate suitable approaches and marketing strategies for each type of group product or service innovation to maximize market share.

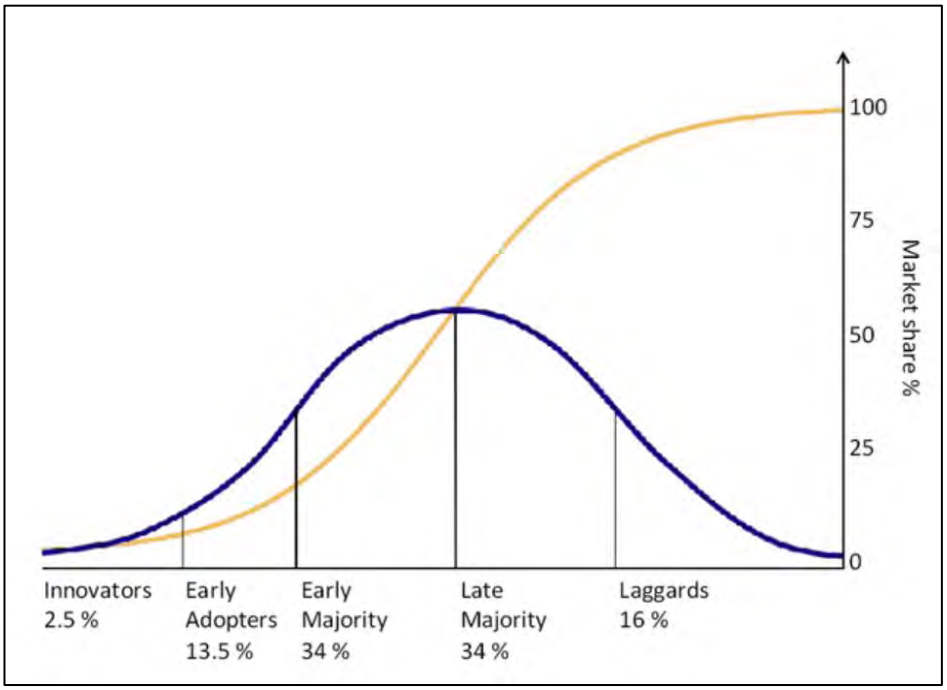


Figure 2-5
DOI's Bell Curve of Five Personality Traits (Rogers, 1995)

There are only a number of studies that utilize only DOI as the underpinning theory, as listed in Table 2-3. Recent trends show a more preferred approach is to combine DOI with other theories such as TAM, UTAUT, Perceived e-readiness, TOE framework, as well as institutional theory (Al Hadwer et al., 2021; Molla & Licker, 2005; H. J. Park & Choi, 2019; Sharma & Mishra, 2014).

Table 2-3
Studies using DOI theory (Rogers, 1995)

Technology Adoption	**Author(s)**
Mobile payments	Dash et al. (2023)
E-Learning	Pinho et al. (2021)
Management Information System	Giua et al. (2020)
Business Intelligence System	Jaklič et al. (2019)
Business Intelligence System	Abdul Jalil & Hwang (2019)

Table 2-3
Studies using DOI theory (Rogers, 1995) (continued)

Cloud Computing	Sallehudin et al. (2015)
Travel platform	Amaro & Duarte (2015)
Social media	Zolkepli & Kamarulzaman (2015)
Interbank mobile banking	Kapoor et al. (2015)
Mobile banking	Al-Jabri & Sohail (2012)
ICT	Jeyaraj et al. (2006)

2.7.2 Technology-Organization-Environment (TOE) Framework

The book, *The Processes of Technological Innovation* (1990), was written about the technological innovation process in its entirety and from both the perspectives of the developer and the user (L. G. Tornatzky & Fleischer, 1990). In Chapters 7 through 9, the perspective was written from the organizational perspective and the TOE framework explicates specifically how internal and external contexts of the firm (technological, organizational, and environmental factors) affect adoption and innovation implementation (DePietro et al., 1990). The TOE framework is considered superior to other theories as it incorporates managerial aspects of organizational context, and thereby complementing the technological and environmental contexts into one single comprehensive framework (Bakar et al., 2024; Gangwar et al., 2015).

TOE framework (Figure 2-6) has emerged as a dominant theoretical framework to study IT adoptions. Its dominance is supported by a number of extant literature review on technology adoption such as an article that covered 330 published papers in ranked IS journals between 2006 and 2015 (Salahshour Rad et al., 2018). In addition, a systematic literature review (SLR) found that TOE framework was the most popular

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foundational model besides TAM, DOI, TPB, TRA and UTAUT. Almost 40 percent, or, 55 out of 142 papers utilizes TOE as the theoretical framework (Zamani, 2022). A recent SLR conducted also found that TOE framework was conclusively the most dominant theory used to study big data analytics adoption (Aldossari et al., 2023), accounting for 40 percent of 60 studies.

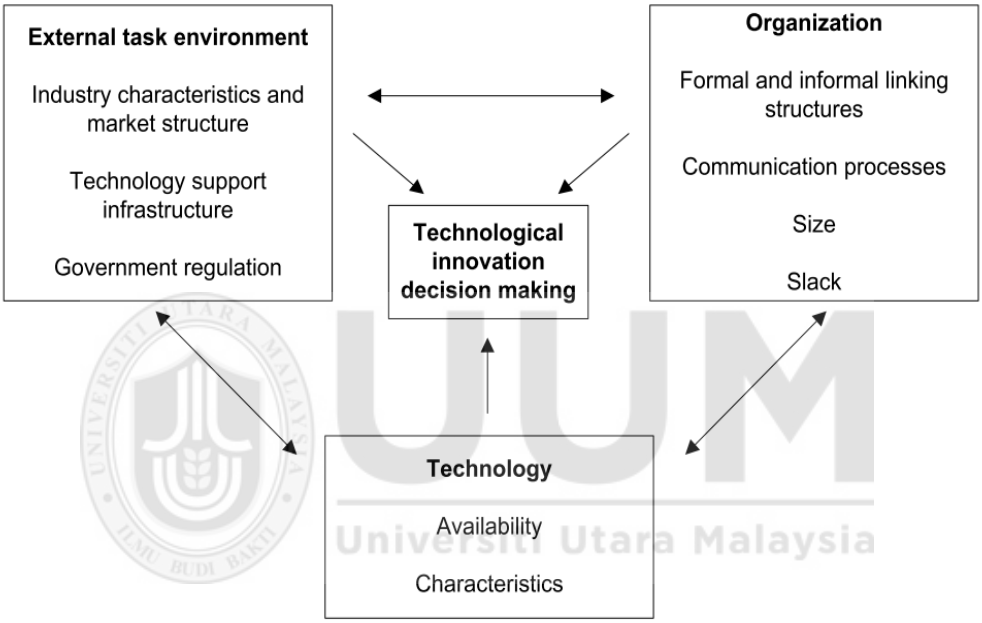


Figure 2-6
TOE Framework by Tornatzky & Fleischer (1990)

Notwithstanding this, extant literature reviews at firm-level technology adoption shows that the TOE framework has been used in combination with other IS adoption theories such as DOI. Besides DOI, the TOE framework has also been combined with other theories such as TAM, TPB, UTAUT theories (Zheng, 2011), and electronic data interchange model (EDI) (Iacovou et al., 1995). Some studies combined it with management theories such as the Institutional Theory (DiMaggio & Powell, 1991; Meyer & Rowan, 1977) to reflect the strategic management implications from

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technology adoption caused by external isomorphic pressures from various stakeholders (Oliveira & Martins, 2011). TOE has also been used in combination with Dynamic Capabilities (Teece et al., 1997) and Resource-Based View (Barney, 1991; Wernerfelt, 1984) theories to extend the explanation into firm performance (Zhu & Kraemer, 2005; Mishra et al., 2007). Conclusively, the TOE framework is most suitable for organizational adoption studies (Al Hadwer et al., 2021).

Similar to DOI theory, TOE framework is a prevalent theory in understanding various IT and technology adoptions (Aldossari et al., 2023; Baker, 2012; Trevor Clohessy & Acton, 2019; Salahshour Rad et al., 2018). This may be contributed by TOE framework's versatility as a "universal" theory (Zhu & Kraemer, 2005) that is well-suited to house a range of factors in adoption studies (Baker, 2012; Jeyaraj et al., 2006). Researches proved that technology and innovation adoption are influenced by multitude of factors that span across several phases and dimensions (Table 2-4), including externalities, contexts, industries and even features of the innovation itself (Rogers, 1995; Tornatzky & Fleischer, 1990; Wolfe, 1994).

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Table 2-4
Studies based on IT innovation adoption factors using the TOE framework

Factors	Dimensions
Technological Context	- perceived benefits or relative advantage - compatibility - complexity - trialability - observability - cost savings/reduction - reliability
Organizational Context	- top management support - firm size - organizational readiness: • technological readiness (IT expertise and IT resources, technical competence, existence of IT department, employee's knowledge); and, • financial readiness (financial resource availability) - CEO characteristics/innovativeness - trust
Environmental Context	- market dynamics - external pressures (customer pressure, intensity of competition, pressure imposed by trading partners, government policies, market uncertainty) - third party (i.e. vendors) - customer readiness - participation level in a professional and trade association - political situation

Source: Author's own compilation

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The TOE theory is named after three components in the organization that affect its adoption decisions, namely, the technological, organizational, environmental (L. G. Tornatzky & Fleischer, 1990). TOE's technological component describes factors that affect technology adoption comprising two dimensions i.e., technological availability and characteristics. These two dimensions include factors such as complexity and compatibility of the new technology adopted. The technological context is focused on how the characteristics of the technology themselves influence adoption as well as potentials that exist outside the firm.

As for the organizational context, it refers to how resources, characteristics and communication mechanisms of the firm affect its adoption decisions. This includes factors such as formal and informal forms of organizational structure; firm size, degree of organizational, as well as human resources and slack resources (Al Isma'ili, 2017). Lastly, the TOE framework's environmental context refers to the industry's competitive characteristics, i.e. market pressure; technological infrastructure support; and government regulation and their effects on adoption decisions (Al Hadwer et al., 2021).

Table 2-5 are select studies focusing only on the TOE framework as the underpinning theory. For example, Alshamaila et al. (2013) conducted semi-structured interviews to study cloud computing adoption among SME service providers in England and identified relative advantage, compatibility, uncertainty, geo-restriction, top management support, external support as significant factors. Meanwhile, another study focused on social media adoption among organizations used relative advantage

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Table 2-5
Studies based on TOE framework (L. G. Tornatzky & Fleischer, 1990)

Type of technology Adoption	**Author(s)**
Big Data Analytics	Maroufkhani et al. (2023)
Mobile Marketing	Maduku (2021)
Cloud ERP	Zamzeer et al. (2020)
Big Data Analytics	Maroufkhani, Wan Ismail, et al. (2020)
Software-as-a-Service (SaaS)	Oliveira et al. (2019)
ERP under Software-as-a-Service (SaaS)	Valdebenito & Quelopana (2019)
Blockchain	Clohessy & Acton (2019)
Business Intelligence System (BIS)	Stjepić et al. (2019)
Smart Manufacturing Information & Digital Technologies	Ghobakhloo & Ching (2019)
Blockchain	Wong et al. (2019)
B2B e-commerce	Mohtaramzadeh et al. (2018)
Mobile payment systems	Khan & Ali (2018)
Big data	Gangwar (2018)
Cloud computing	Hassan et al. (2017)
Social media	Tajudeen et al. (2017)
Information Systems (IS)	Awa et al. (2016a)
Mobile Marketing	Maduku et al. (2016)
Cloud computing	Gutierrez et al. (2015)
Enterprise Architecture	Ramdani et al. (2013)
Cloud computing	Alshamaila et al. (2013)

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compatibility, cost effectiveness, structural assurance and interactivity of social media (Tajudeen et al., 2017).

At this juncture, notice that extant studies opted to use DOI's innovation attributes (relative advantage, compatibility, complexity, observability, and trialability) as TOE's technological factors. Moreover, in the organizational context, The TOE framework is found to be aligned and comparable with DOI adoption predictors: individual and internal characteristics studies (Baker, 2012; Jeyaraj et al., 2006). Only in the environmental context of TOE framework is said to be complementary to DOI's external characteristics (system openness) since the former specified a more detailed dimension of the construct (Al Isma'ili, 2017; Oliveira & Martins, 2011). A crucial difference between these two theories is that TOE does not include the role of individual characteristics such as top management support; whereas DOI does not include environmental context per se. Therefore, it is meaningful to integrate these theories together in this study.

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Additionally, top management support as a mediator in the TOE framework received little empirical attention. Positioning top management support as a mediator extends the TOE framework and leads to better understanding of the study. Table 2-6 shows a number of recent studies employing a combination of DOI theory with the TOE framework in technology adoption.

Table 2-6
Studies based on combination of DOI theory and TOE framework

Type of technology Adoption	**Author(s)**
Business Intelligence Systems	Salisu et al. (2021)
e-marketing	Alrousan et al. (2020)
Blockchain	Wong et al. (2019)
Cloud-based enterprise resource planning	Usman et al. (2019)
Digital innovation	Park & Choi (2019)
BIS	Puklavec et al. (2017)
Digital information and technology	Molinillo & Japutra (2017)
Enterprise resource planning	Ilin et al. (2017)
Cloud computing	Wilson (2017)
Cloud computing	Kumar et al. (2017)
Broadband mobile applications	Chiu et al. (2017)
BIS	Miskon et al. (2015)

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In conclusion, it can be established that studies used the TOE framework by employing varying factors for each of the technological, organizational, and environmental contexts. Essentially, researchers agree with all three contexts of the TOE framework, but the general consensus is that there is not an established or specific factor for each of them (Baker, 2012). As such, each empirical study proposes its own set of factors depending on the adoption being studied. A compilation of studies and dimensions used to test TOE is tabulated in Table 2-7.

Table 2-7

TOE Adoption Factors in Studies

Source	**Technological Factors**	**Organizational Factors**	**Environmental Factors**
1. Bakar et al. (2024)	relative advantage*, cybersecurity*	top management support*, adoption cost*	government support* and business partner*
2.Wong et al. (2019)	relative advantage*, complexity*	upper management support, cost*	market dynamics, competitive pressure* and regulatory support
3.Usman et al. (2019)	relative advantage*, cost savings*	top management support*, firm size*, knowledge*	competitive pressure* and regulatory support~
4.Ghobakhloo & Ching (2019)	perceived value*, perceived cost*, perceived compatibility*	strategic road mapping*, knowledge and competency*, information processing requirement*	imposition by environment*, competitive pressure~
5.Junior et al. (2019)	relative advantage*, compatibility*, complexity~,	top management support~, technology competence~,	competitive pressure*, industry*
6.Puklavec et al. (2017)	relative advantage~, cost~, BIS integration with ERP*	management support*~, organizational readiness*~, culture*~, project manager*~	external support~
7.Mohtaramzadeh et al. (2018)	perceived relative advantage~, cost of adoption*,	top management support*, IT infrastructure~ and capabilities	competitive pressure*, trading partner pressure~, government support*, legal infrastructure ~
8.Hassan et al. (2015)	perceived benefits~	IT resources*, top management support~	external pressure*
9.Ramdani et al. (2013)	relative advantage*, compatibility*, complexity*, trialability*, observability*	top management support*, size*, organizational readiness*	industry*, market scope*, competitive pressure*
10.Alshamaila et al. (2013)	relative advantage*, uncertainty*, geo-restriction*, compatibility*, trialability*	size*, top management support*, prior experience*, innovativeness*	industry*, market scope*, supplier efforts* and external computing support*, competitive pressure

Note: ** significant* *~ insignificant* **~ partially significant*

Source: Author's own compilation

2.7.3 Firm Strategy Typology

Generally, corporate strategic planning entails establishing organizational strategies (Hax & Majluft, 1983) such as corporate-level, business-level strategy, and functional-level strategies. Corporate-level strategy applies to the entire entity and delineates the businesses wherein a company competes (Schmidt & Redler, 2018). On the other hand, business-level strategy concerns a business unit within a company compete to achieve market advantage (Hambrick, 1980) instead of the entire company. Lastly, as per its name, functional-level strategies relate to the various functions in a company such as IT, finance and human resource strategies (C. Matt et al., 2015).

In recent times, as industries step up initiatives to leverage technological benefits, they need to formulate a digital transformation strategies (Chanias et al., 2019; C. Matt et al., 2015). In particular, an SLR on technology adoption among SMEs (Zamani, 2022) specifically raised concerns that among a total of 349 papers that researched, only a minimum number of research studied a strategy concept. In the same vein, a digital strategy is a fusion view wherein technology and business strategy are parallel (Chanias et al., 2019). This requires the business and IT strategies to be aligned with the digital transformation strategies (C. Matt et al., 2015). In the digital era, a major impediment to SMEs' growth and sometimes survival strongly points to their failure to align digital strategy and business (Kitsios & Kamariotou, 2019; Li et al., 2016).

For the past four decades, the Miles and Snow strategy typology (1978) has been widely used in many empirical studies and more importantly, it is the most proven organizational strategy categorizations (Ingram et al., 2016). A crucial point made by Miles & Snow (1978) in the introductory paragraph is an organization's ability in

executing alignment task to maintain a viable market. Efficient organizations are able to achieve strategic alignment to their structural and process mechanisms that successfully complement their market strategy. To this end, a process dubbed the adaptive cycle is viewed as three broad "problems": the entrepreneurial problem, the engineering problem, and the administrative problem, all of which must be handled by management concurrently (Miles et al., 1978).

Interestingly, similar to the TOE framework, the engineering problem in Miles and Snow (1978) is characterized by the limitations due to the characteristics of the organization's present technology (technological context), as well as the limitations due to the skills of the employees (organizational context). It is also noteworthy that the responsibility of entrepreneurial function rests with the top management, although the lower management levels could have identified the opportunities and initiate the efforts towards solving it (Miles et al., 1978). In order to solve the entrepreneurial problem, the management would be facing an engineering problem, i.e., by operationalizing an appropriate system or technology (Gumusluoglu & Acur, 2016; Miles et al., 1978). Finally, the administrative problem is basically streamlining and stabilizing activities that are necessary to solve the entrepreneurial and engineering problems, while concurrently allow for future innovation (Gumusluoglu & Acur, 2016; Miles et al., 1978). In solving these three problems, organizations move through the adaptive cycle depending on their main typology (defenders, analyzers, and prospectors), and consistent with the interplay between its strategy with its technology, structure and process. Conversely, the fourth strategy type, reactor, is when strategy incoherence is seen in the way organizations respond in the adaptive cycle (Miles et al., 1978).

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A Defender is characterized by its main strategy to ensure stability by focusing on a niche product and market, and by aggressively protecting its turf so it is difficult for competing companies to enter. Defenders will also handle engineering and administrative problems with a priority on efficiency, usually with a highly cost-efficient single core technology. Therefore, in the face of disruptive technologies such as the 4IR era, defenders would encounter tremendous challenges and risks in the adaptive process.

On the other hand, a Prospector is almost the opposite of the Defender. The Prospector's primary capability is to find and exploit new product-market opportunities; and it is of utmost importance to uphold its reputation in the industry as innovators. As innovators, the Prospector's main weakness is the inherent riskiness to its innovativeness that may jeopardize its profitability. Contrary to the Defender, the Prospector uses change as a major tool to gain an advantage over competitors. Hence, the Prospector requires flexibility in its technology and administrative systems, whereby the organization would prioritize diverse technologies that minimizes routinization and mechanization. Similarly, the Prospector's administrative system would be decentralized, yet facilitative and well-coordinated. The flexibility in its approach would pose a risk of low profitability and inefficiency to the Prospector, but well-suited to the 4IR era.

Finally, the Analyzers is in the middle of the adjustment strategy continuum between the Defender and the Prospector. The Analyzer is the most suitable strategy typology in technology adoption. It is able to perfectly balance maximizing opportunities like the Prospector, but at the same time is able to minimize risks like the Defender. It is a

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difficult strategy to pursue especially for SMEs, as the Analyzers is trying to accomplish and protect an equilibrium between being flexible and innovative and yet efficient and stable.

All three types of organizations aforementioned, i.e., the Prospector, the Defender and the Analyzer, are consistent in their solutions and proactiveness in adapting to the three problems aforementioned. The Reactor, on the other hand, is characterized by inconsistent and unstable patterns of adjustment to its environment. In short, the Reactor is a residual strategy that arises when one of the other strategies are pursued incongruously (Conant et al., 1990). The reasons contributing to Reactor strategy could be due to top management not articulating the organizational strategy clearly to the whole company; the organization structure does not fit the chose organizational strategy; and finally, the management continue to uphold the current strategy and structure even when faced with tremendous change in its environment (Miles & Snow, 1978). This reactive approach typically leads to instability and poor performance. In conclusion, a company's strategic type would inform top management's role in technology adoption (Anwar et al., 2025). Hence, profiling the SMEs will reveal how the various archetypes strategically embark on a digital transformation.

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2.8 Research Framework

The main objective of the study is to analyze the factors affecting 4IR technology adoption by SMEs from the perspectives of an organization as the unit of analysis. The research framework for the study is based on two underpinning theories, namely the DOI theory and the TOE framework to determine the relationship between the technological, organizational and environmental factors and the mediating factor, top

management support, on 4IR technology adoption. Miles and Snow strategy typology theory will only serve to profile the SMEs and will not be part of the research framework.

Moving forward, this section will discuss the research framework for this study as demonstrated in Figure 2-7. Only constructs relevant to the context of this research are selected, justified, and explicated. The dependent variable (DV) is 4IR technology adoption by SMEs. The hypotheses from H_1 to H_{13} are based on constructs under technological, organizational, and environmental contexts from the DOI theory and the TOE framework. Based on an SLR conducted in 2020 (S. Ahmad et al., 2020) which covers 84 empirical studies between 2011 and 2020, the study's research framework is based on factors ranked in the top five in each TOE contexts. The technological context covers three of the top prominent constructs, i.e., relative advantage, complexity, and cost. Next, the organizational context covers two constructs, i.e., top management support, and size of firm. Finally, the environmental context covers two constructs, namely government support, and competitive pressure. Meanwhile, the hypotheses for mediator construct, top management support, are represented by H_8 to H_{13}. Each of these hypotheses will explain the mediating effects between top management support and the individual multivariate constructs in the technological, organizational, and environmental contexts on 4IR adoption.

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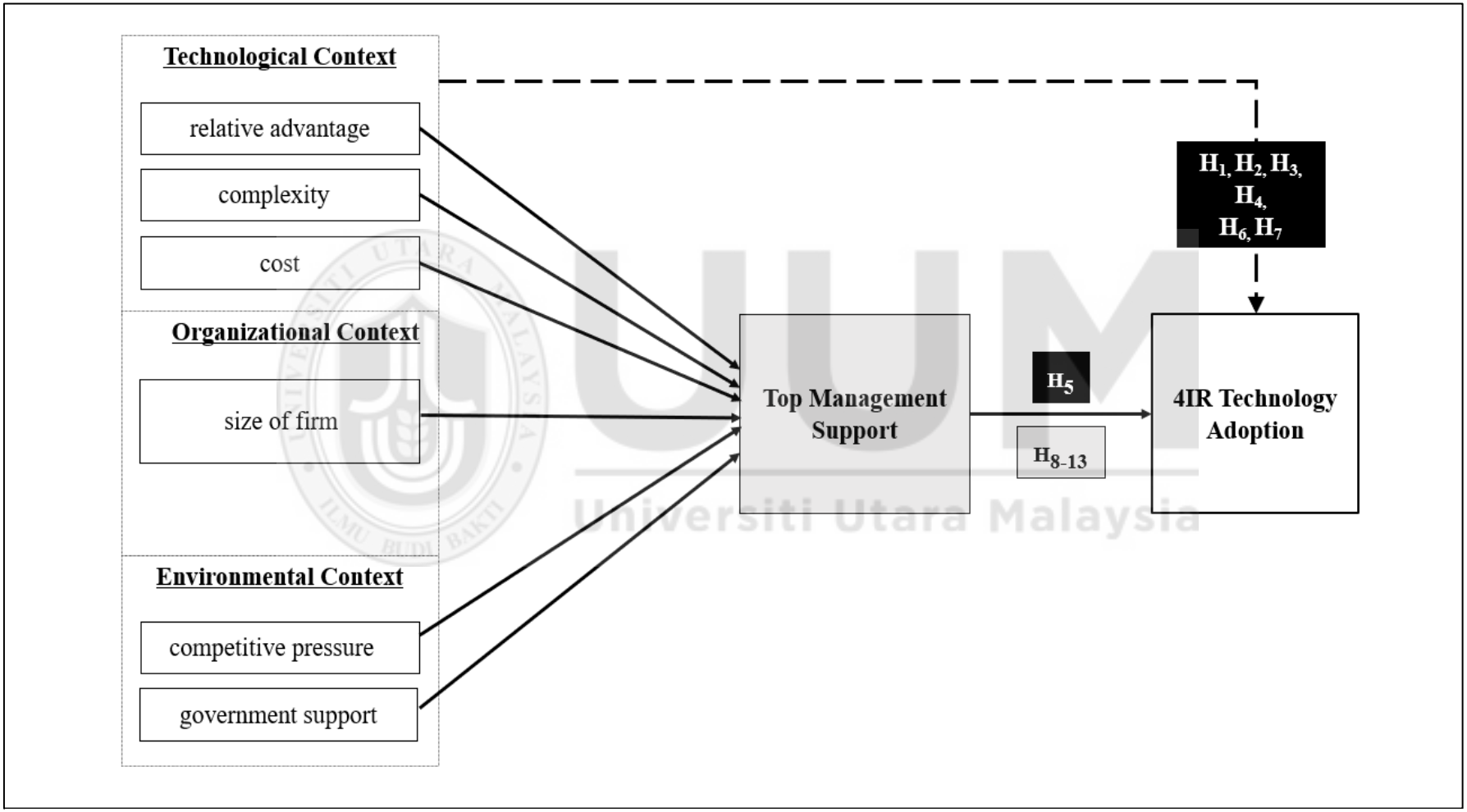


Figure 2-7
The Research Framework

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2.9 Hypothesis Development

Subsequent to the research framework in Figure 2-7, this section will discuss the hypothesis development based on the research objectives of the study. As mentioned earlier, the DOI theory and the TOE framework will serve as a basis of understanding the relationships between constructs of this study. Hypotheses H_1 through H_7 are developed based on research objectives one, two and three. All seven hypotheses are related to the direct effect of each independent variable in the technological, organizational, and environmental contexts on the dependent variable (DV), 4IR technology adoption. Then, hypotheses H_8 through H_{13} are based on the fourth through sixth research objectives, which is to gain insight about the relationship between the mediating variable, top management support, and its effect on the DV, 4IR technology adoption.

2.9.1 Relative advantage and 4IR technology adoption

Relative advantage would be 4IR technologies adoption that is advantageous to the SMEs in terms of economic, technology or social extents (Rogers, 2003). As a company, SMEs would focus on the economic benefits such as cost savings, higher productivity, and expansion of new markets. Besides, SMEs will also enjoy technological benefits such as informed decision making and better service delivery (Maroufkhani, Tseng, et al., 2020). To a large extent, technology adoption can benefit an SME by improving its productivity and competitiveness (Alshamaila et al., 2013; OECD, 2019a). In the context of 4R technology adoption, if SMEs gain access to scalable technology, they quite possibly could compete in new markets previously dominated by large firms (Alshamaila et al., 2013). In this study, relative

advantage construct under the technological context is expected to positively effect 4IR technology adoption, whereas complexity and cost (of adoption) are expected to have a negative effect on 4IR technology adoption.

Numerous empirical studies sought to determine the relationship between relative advantage and a specific type of technology adoption. One recent study was conducted by Yaseen et al. (2022) concluded that relative advantage significantly affected the adoption of cloud computing among 244 registered SMEs in Jordan. Another study among Jordan SMEs on big data analytics (BDA) adoption, Lutfi et al. (2022) concluded that relative advantage was a significant influence. Additionally, in Kuwait, research among 259 SMEs found that relative advantage significantly affect e-commerce adoption (Mohd Isa & Alenezi, 2022). Of note, relative advantage was identified to be significant as a critical success factor in a qualitative study among 20 small business managers in the UK among 16 factors (Eze et al., 2018).

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On the other hand, some studies found that relative advantage was not significant in influencing technology adoption. For instance, a study on business information systems (BIS) adoption in Slovenia which was participated by 181 SME senior management concluded that relative advantage was not a significant factor (Puklavec et al., 2018). Similarly, Mohtaramzadeh et al. (2018) examined the factors affecting B2B e-commerce adoption among 320 Iranian SME business owners and managers in the manufacturing sector, using PLS-SEM technique. The results showed that relative advantage did not significantly influence B2B e-commerce adoption. In the same vein, a study in Malaysia that only focused on technological context among the SMEs found

relative advantage did not have a significant relationship with cloud computing adoption (H. Hassan & Nasir, 2017).

As discussed above, results based on previous studies appeared to be varied and thus merits a study on the relationship between relative advantage and 4IR technology adoption. Thus, this study proposes the following hypothesis:

H_1: *Relative advantage is positively related to 4IR technology adoption among SMEs.*

2.9.2 Complexity and 4IR technology adoption

The adoption of any new technologies would present a tremendous challenge to companies, particularly, the SMEs. Rogers (1995) stated that the more complex the technology, the less likely the 4IR technology adoption would happen. Unlike relative advantage, SMEs that find 4IR technologies to be of higher complexity, and thus, would be less likely adopt them. A recent SLR (Aldossari et al., 2023) compiled a list of determinants of BDA adoption among SMEs ranked complexity second out of 42 from their review of literature. In the SLR, for instance, Maroufkhani, Tseng, et al., (2020) surveyed 171 Iranian SME manufacturers and concluded that complexity significantly and negatively affect BDA adoption. The study found that complexity factor lies in the level of difficulty in the technology itself, whereby the survey revealed that employees find it quite difficult to learn, maintain and operate BDA. Likewise, studies by Skafi et al. (2020) in Lebanon, and Pathan et al. (2017) in Pakistan confirmed that complexity is a deterrent factor in the adoption of cloud computing. Finally, in a study of AI adoption among 391 Indian manufacturers also prove to be aligned with previously discussed research (Chatterjee et al., 2021).

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Another study by Hassan & Nasir (2017) investigated the factors of cloud computing adoption among Malaysian SMEs' mid- to senior-level executives and managers in the services and manufacturing sectors. Choi et al. (2020) demonstrated that due to complexity factor, companies will be slower to adopt blockchain technology. Both studies also coincided with findings from the previous studies discussed, such that complexity was significant and negatively affecting cloud computing adoption. Understandably, the difficulty in comprehending and implementing a new technology poses an increase in related risks; hence, brings about higher resistance and failure in the organization adopting it (Hassan & Nasir, 2017).

In a different methodology approach to study complexity, a qualitative study carried out in India (Verma & Bhattacharyya, 2017). The results also found to be congruent with earlier discussed findings whereby Indian companies find complexity to be a significant factor towards BDA adoption. Apart from that, Lutfi et al. (2022) also determined that in a developing country like Jordan, complexity plays a significant role in the adoption of big data analytics among the SMEs.

Other studies such as the one in Queensland, Australia focused on local governments' cloud computing adoption (Ali et al., 2020). The study found significance in the relationship between low complexity and cloud computing adoption. Nevertheless, the study by Ali et al. (2020) interestingly found that complexity is in fact a positive factor in cloud computing adoption. An explanation offered was, these public organizations similar to local governments have a different primary objective, which is to provide public services to their constituents. On the other hand, the benefits of adoption such as automation across organization functions and processes essentially decreases the

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complexity of the new technology adopted (Ali et al., 2020). Additionally, the positive relationship with cloud computing adoption among SMEs could be explained by the complexity factor being viewed as an opportunity to improve competitiveness (Sithole & Ruhode, 2021).

Inversely, a few studies proved that complexity is not a significant factor in influencing adoption of technologies. For example, Gangwar (2018) quantitative study sought to compare manufacturing and services sectors in India. It was revealed that complexity factor had no significant relationship with big data adoption among the SMEs in the manufacturing sector. Similarly, results in a research by Safari et al. (2015) also found to be congruent in which there is no significant relationship between complexity and cloud computing adoption among Iranian SMEs. Drawing on the various findings above, the hypothesis formulated for this study is:

H2: *Complexity is negatively related to 4IR technology adoption among SMEs.*

2.9.3 Cost and 4IR technology adoption

An SLR article by Ahmad et al. (2020) listed cost as the top five out of 93 determinants of business intelligence systems (BIS) adoption studied between 2011 and 2020. Cost of adoption is uncertain depending on the technology and includes setup costs, hardware, software, recruitment, training costs; as well as indirect costs such as maintenance costs, switching cost (Choi et al., 2020; Seethamraju, 2015) and administrative costs (Choi et al., 2020). A study on B2B e-commerce technology adoption (Mohtaramzadeh et al., 2018) concluded that cost of adoption has a negatively significant relationship, which means that the higher the cost, the lower the technology adoption. Choi et al. (2020) also found that high startup costs will be a

major barrier in technology adoption such as blockchain; although there will be expected cost savings to be realized after implementation.

In two separate qualitative studies in India, Verma & Bhattacharyya (2017) and Kumar & Krishnamoorthy (2020) attributed many SMEs perceiving the initial and operations costs of adoption as a key barrier to big data analytics adoption. Verma & Bhattacharyya (2017) study utilized semi-structured interviews, followed by use of secondary data from sources such as government publications, industry reports, analyzed using content analysis method. In total, 22 practitioners were interviewed via telephone and one-on-one interviews. Using similar methods, Kumar & Krishnamoorthy (2020) interviewed 24 respondents who are Chief Technology Officers, senior IT and business analytics professionals to derive the same conclusion about cost of adoption. Interestingly, a qualitative study by Clohessy & Acton (2021) that interviewed eleven large companies and nine SMEs in Ireland reported that regardless of firm size, interviewees expressed the importance of cost effective, pay-as-you-go cloud development platforms.

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In contrast, a study on the relationship between cost and blockchain adoption in the construction industry (X. Wang et al., 2022) arrived at an opposite outcome. Cost of adoption was found to be not a significant negative factor in this empirical study. A possible explanation given was that since blockchain technology is still at infancy stages in the construction industry. Thus, respondent practitioners may not have fully grasped the total cost of adoption involved in the decision to adopt the blockchain technology ad deemed cost not to be a factor. A recent study by Abdul Rasheed & Nafiz (2022) investigated the relationship between cost and social media marketing

adoption among SMEs in Maldives. The finding is consistent with Wang et al. (2022) albeit for a different reason; cost of marketing on social media platforms are cheaper in comparison with traditional mass media options such as billboards, or television network. This would explain the reason for non-significance of the relationship between cost and social media marketing adoption. Given that the discussions above proved a mixed finding, the study postulates the following hypothesis:

H3: *Cost is negatively related to 4IR technology adoption among SMEs.*

Next, this study will explicate prior studies and develop hypotheses for TOE framework's organizational context by focusing on two constructs, namely, size of the firm and top management support. Both factors have been found to be very vital and positively impact technology adoption (Ramdani et al., 2013; Zakari Usman et al., 2019).

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2.9.4 Firm size and 4IR technology adoption

Rogers (1995) posits that the bigger the size of an organization, the more innovative it would be. Notwithstanding that, he observed that this is counterintuitive, as smaller firms seemed more flexible. A study was conducted in Türkiye and 9 countries (Jordan, Lebanon, Saudi Arabia, Bahrain, Qatar, The United Arab Emirates, Egypt, Oman, and Kuwait) in the Middle East (AL-Shboul, 2019). The methodology employed was logistic regression with 131 respondents, to pinpoint main determinants of SMEs in developing countries in deciding whether or not to adopt cloud enterprise resource planning (ERP). Conclusively, the enterprise size was found to be positively and significantly related to the cloud ERP. This study attributed the fact that large

enterprises possess more resources compared to small- and medium-sized enterprises, and as such, could take more risks. A different study on cloud ERP was conducted in Nigeria by Usman et al. (2019), targeting manufacturing SMEs. The same conclusion was reached by this study, similar to the study by Usman et al. (2019).

Two studies investigating cloud computing adoption among SMEs were conducted by Pathan et al. (2017) and Yaseen et al. (2021), in Pakistan and Jordan, respectively. Both studies found that firm size is positively related to cloud computing adoption. Aside from the explanation given concerning the resources limitation and hence risk-aversion compared to larger companies, Pathan et al. (2017) also elaborated on the resource limitation issue by zeroing in the dimensions of firm size construct used in their study, which is a measure of manpower, market size and total capital investment. Yaseen et al. (2021) on the other hand posited that to mitigate resource limitations, smaller firms would adopt variations of "pay-per-use" or cheapest subscription instead.

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Conversely, there are evidence to the contrary which proved that firm size is not a significant factor in technology adoption. A multi-method qualitative study using content analysis and multiple-case study methods interviewed twenty companies in Ireland (Trevor Clohessy & Acton, 2019). It was observed that large companies are more likely to adopt blockchain compared to SMEs in a developed country. Out of 20 companies, a total of nine SMEs were interviewed about blockchain technology adoption. Out of the nine SMEs, the adopters cited the primary reason for the decision to adopt blockchain was specifically due to its "single instances of application," or

trialability. Thus, the study concluded that firm size was the weakest factor in this study, and that other managerial-related factors were superior drivers.

In a study by Skafi et al. (2020) focused on firm size as a determinant factor in cloud computing. They determined that firm size has no relationship in cloud computing adoption as unlike large companies, these smaller companies, startups included, did not have legacy technology that would be harder to replace and more complication in terms of business processes to be tackled. Similarly, Senyo et al. (2016) who studied factors of cloud computing adoption in Ghana, also concurred with the findings by Skafi et al. (2020). Finally, Wang et al. (2016) researched the determinants of Taiwan mobile reservation system adoption and consistently found that the hoteliers did not consider their firm size as a determinant factor. In the context of 4IR technology adoption in Malaysia, it would be interesting to see if size still play a significant role in the factors of 4IR adoption. Based on this discussion, it is proposed that:

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H₄: *Firm size is positively related to 4IR technology adoption among SMEs.*

2.9.5 Top management support and 4IR technology adoption

According to Tornatzky et al. (1990, pg: 159), it is not just the organization structure that provides an impetus for technological innovation. Just as important are the events or processes that occur which is key in establishing conducive environment for technology adoption, namely informal linkages and communication, as well as top management strategic behavior. Top management support (TMS) refers to the extent of support received from senior management of an organization in the adoption of technology (Abdul Rasheed & Nafiz, 2022). Prior studies have established that top

management support is a crucial driver of technology adoption (Bhattacharyya & Shah, 2022; T. Clohessy et al., 2020; A. Lutfi et al., 2022). This is because top management provides an essential and appropriate resources to enable technology adoption in the organization (Lin, 2014). Consequently, it follows that higher support from the top management would encourage technology adoption by the organization. A recent SLR (Aldossari et al., 2023), which endeavored to identify key factors in BDA adoption among SMEs ranked top management support at the third highest factor out of 42 and the number one factor as ranked by the experts.

An empirical study by Lutfi et al. (2022) studied the relationship between top management support and big data analytics in Jordanian SMEs. The responses received from 119 hotel via an online questionnaire indicated a consistent finding that top management support is a significant factor of technology adoption. Clohessy & Acton (2019) conducted a study in Ireland to elucidate factors impacting technology adoption in developed countries. They opted for a multi-method qualitative study using content analysis and multiple-case study method of twenty companies in Ireland and found that top management support emerged as the significant enabler in blockchain adoption. Another qualitative study in India by Verma & Bhattacharyya (2017) also supports the finding that top management support is a critical factor in big data analytics adoption. The study utilized multi-method approach using semi-structured interviews and content analysis to arrive at this conclusion.

On the contrary, Abdul Rasheed & Nafiz (2022) conducted a study to determine the relationship between TMS and social media marketing adoption among SMEs in Maldives. They established that TMS was not a significant factor with the reason being

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that the companies' top management was already receptive towards adoption of social media marketing. This is evident from the age of the respondents who were relatively young (under 45 years old) and in general are familiar with social media use. A related study in social media adoption by (Qalati et al., 2022) also found top management support as a non-significant factor.

In a cloud computing adoption study (Haslinda Hassan et al., 2017), top management support was irrelevant as Malaysian SMEs have access to free services such as Dropbox, which did not require any financial commitment. Moreover, as an SME, their size may be small enough to not justify approvals from top management to adopt sophisticated and costly cloud computing services. Sithole & Ruhode's (2021) and Wang et al. (2016) research was also congruent with the finding of the two prior studies discussed. Wang et al. (2016) conducted a study in Taiwanese hoteliers' adoption of mobile reservation system also found that TMS is not significant. The explanation offered was that adopters and non-adopters top management support average scores differ only by 0.01 (adopters: 4.74; non-adopters:4.73), which is very indistinguishable as a factor of adoption. The above discussions resulted in the following:

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H_5: *Top management support is positively related to 4IR technology adoption among SMEs.*

The final context in the research framework is the environment factors. Two dimensions are relevant in this study, namely, government (regulatory) support and competitive pressure. Review of literature indicates that both these environmental factors of have significant effects on 4IR technology adoption (A. A. Lutfi, 2017; Msomi, 2019).

2.9.6 Competitive pressure and 4IR technology adoption

Competitive pressure is defined by the degree of pressure stemming from industry competition (Zhu & Kraemer, 2005, p. 70). Many researchers stipulated that competitive pressure is the environment of competition influencing the organization to adopt a technology in order to remain or improve competitiveness (D. Q. Chen et al., 2015; Chwelos et al., 2001; Gangwar, 2018). Porter and Millar (1985) explained that competitive pressure is a driver of technological innovation based on strategic rationale. As a result, firms that adopt advanced technologies such as AI could disrupt the industry's competitive landscape by altering rules of competition or affecting industry structure. Prior empirical studies also found that pressure from competitors would be a major determinant in whether or not an SME would adopt a 4IR technology. Msomi et al. (2019) conducted a survey among manufacturers in South Africa. The results show alignment with previous studies in which competitive pressure did in fact show significance in the adoption of management accounting practices.

A cloud computing adoption study was conducted by Sithole & Ruhode (2021) among SMEs in South Africa and Senyo et al. (2016) among large companies in Ghana, found that there is a significant and positive relationship with competitive pressure. This has been attributed to their competitors adopting the technology to attract and retain customers by improving service levels and hence, their experiences and loyalty. Gangwar (2018) determined that competitive pressure is positive and significant factor in the adoption of big data among 478 SMEs and large companies in the manufacturing and services sectors. Zhu et al. (2006) concluded that stiffer competition among competitors will accelerate adoption at the expense of a more holistic technological

adoption approach. In other words, organizations will expedite 4IR technology adoption as a stratagem to avoid lagging behind or to gain an advantage over competitors.

Similarly, the same relationship was determined in a study by Asiaei & Ab. Rahim (2019) among 209 Malaysian SMEs on cloud computing. The study also highlighted the advantages of cloud computing are its almost zero barrier to entry due to subscription-based pricing model; enhanced operational competence and improved responsiveness, hence providing cost savings and increased productivity (Misra & Mondal, 2011). Given these benefits, failure for these small companies to embrace technologies will prove to be their detriment as they will lose opportunities that could potentially give access equal to those of large companies.

A qualitative study using the TOE Framework in India studying business analytics adoption carried out by Kumar & Krishnamoorthy (2020) also supported that the same conclusion. Many organizations interviewed expressly stated that they do monitor if competing firms are using business analytics and if there is good analytical competition from the competitor, they too will adopt it. Another qualitative study was done in Jordan (Zamzeer et al., 2020) to explore the influencing factors of cloud ERP adoption among thirteen interviewees SMEs and cloud ERP technology providers. It is interesting to note that in this study, the technology providers opined that competitive pressure is an important factor; yet the SMEs interviewed all confirmed otherwise. To the SMEs, it is more important for them to adopt cloud ERP in order to gain market share.

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On the opposite end, there are a number of studies such as by Lutfi et al. (2022) who confirmed that competitive pressure was not a significant factor in the adoption of big data analytics among SMEs in Jordan. There is low adoption of big data analytics among the local companies and not much presence of international competitors, which would explain the competitive pressure not being a factor of adoption. In another study, Skafi et al. (2020) also found that competitive pressure is not significant in cloud computing. Their study was conducted among a wide range of industries within a developing country i.e. Lebanon, and thus, found contradictory to studies carried out in developed countries, whereby the competition would be fiercer and would drive adoption. A study on big data analytics adoption conducted in Iran among 171 SME manufacturers (Maroufkhani, Tseng, et al., 2020) also concluded the same finding and provided comparable reasoning as Skafi et al.'s (2020) study. Following a mixed finding as discussed above, this study derived the following hypothesis:

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***H_6**: Competitive pressure is positively related to 4IR technology adoption among SMEs.*

2.9.7 Government support and 4IR technology adoption

Government or regulatory support refers to policies, initiatives, fundings, tax or other financial incentives, infrastructure, as well as agencies established by government to encourage the adoption of technologies (Hasani et al., 2017). Empirical studies have shown that government support is imperative in technology adoption, which means the higher the government support given to companies, the greater the technology adoption in the country (Hasani et al., 2017; Mohtaramzadeh et al., 2018; Owusu-Ansah, 2018). Empirically, for instance in studies in the Middle East by AL-Shboul

(2019) and in Ghana by Senyo et al. (2016), government support falters as a significant factor for technology adoption in countries that are volatile, poor infrastructure, or have unfavorable policies or laws (e.g. affirmative action or, labor laws). Choi et al. (2020) stated that even so, the absence of government support did not mean that companies would forego technology adoption altogether for their company.

In a mixed methodology study by Hoque et al. (2016), found that lack of government support have a statistically significant and negatively relationship with ICT adoption among SMEs in Bangladesh. This means the more support is given by the government, the more ICT adoption will occur. Qualitatively, the data from fifty interviewees from three SMEs indicated that the change of participation in government and donor agencies resulted in creating positive attitude and more efficient employees to use ICT. Lutfi et al. (2020) also concluded that government support had a positive and significant effect on big data adoption among SMEs in Jordan; specifically, in the role the government plays in incentivizing big data adoption by providing financial incentives and technical skills to supplement SMEs with limited resources.

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In fact, Msomi (2019) and Hassan et al. (2015) identified government funding as key to SME digital transformation through technology adoption. Another study on B2B e-commerce technology adoption (Mohtaramzadeh et al., 2018) confirmed that government support has a positively significant relationship. The study highlighted how government support can directly influence adoption of B2B e-commerce in Iran via three-pronged approach; namely, instituting appropriate laws and regulations; providing incentives particularly financial and economic incentives; and finally, improving IT infrastructure. Skafi et al. (2020) contextualized Lebanon as a turbulent

country and thus, lacking government support that proved to be significant as drivers of cloud computing adoption among SMEs, such as IT infrastructure.

Nevertheless, there are a number of studies did not find government support to be significant in their studies. Ali et al.'s (2020) research rejected the hypothesis that government regulation factor has a positive and significant relationship with cloud computing adoption among local governments in Queensland, Australia. This is contrary to the finding by Lutfi et al. (2022), which also studied government regulation as a factor but in a developed country. The explanation given was that during policy formulation there was limited engagement with the local governments as a stakeholder (Ali et al., 2020). Government support was also not significant in a study in the Middle East (AL-Shboul, 2019) in the context of cloud ERP adoption. Finally, Hamad et al. (2018) investigated e-commerce adoption among SMEs in Egypt and revealed that government support did not have a relationship with this technology adoption. Again, political instability in the country was the main reason cited that detracted government from providing the necessary infrastructure and legislation to encourage technology adoption. Therefore, the study hypothesized government support as follows:

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H_7:Government support is positively related to 4IR technology adoption among SMEs.

2.9.8 Top management support as a Mediator

Extant literature shows that top management support is a critical factor in driving technology adoption (Aldossari et al., 2023) and has increasingly been demonstrated in recent studies as a mediating variable in the adoption of 4IR technologies (El-Haddadeh et al., 2021; Maroufkhani et al., 2023). This is because organizational

actions are based on the decisions made by the top executives in the company. It is particularly relevant for SMEs, which typically have smaller number of employees and thus adopt flatter organizational structures, whereby decisions are made by the top management or owner. Top management has the power (Zhou & Zheng, 2023) to decide allocations of essential and appropriate resources necessary to enable technology adoption in the organization (Abdul Rasheed & Nafiz, 2022; Lin, 2014). They would also influence the behaviors in accepting the technology adoption (Abdul Rasheed & Nafiz, 2023; Hassan et al., 2023) through digital leadership (Zhou & Zheng, 2023).

Top management support can be broken down into two aspects i.e. beliefs and participation (D. Q. Chen et al., 2015; Liang et al., 2007). For instance, in the technological context of this study, it depends on the top management's belief that the relative advantage would bring forth economic profitability and competitive advantage to the company, only then will the company adopt the technology. Likewise for the other two barriers of 4IR technology adoption, complexity, and cost. If the top management believe that the complexity and costs of the technology is surmountable, then support in the form of necessary resources would be allocated towards the technology adoption (Maroufkhani et al., 2023).

Ostensibly, this is because SMEs are not laden with legacy technology or lengthy change management exercises to digitally transform the company through 4IR technology adoption. Finally, top management support could be seen mediating the environmental constructs (D. Q. Chen et al., 2015; Liang et al., 2007) in TOE framework, i.e., competitive pressure and government support. Top management

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would be aware of the competitive pressures and strategically adopt 4IR technologies to gain a competitive advantage and increase market share. Finally, top management would fully leverage on the government support provided to boost 4IR technology adoption, and thereby circumvent issues in their companies such as limited financial resources and technical expertise for their employees. Nevertheless, scant studies have researched top management support as a mediator that influences the relationship between the individual TOE constructs and 4IR technology adoption (Abu Hassan et al., 2023; Teh et al., 2024). Thus, this study developed the following six hypotheses:

H_8: Top management support positively mediates the relationship between relative advantage and 4IR technology adoption among SMEs.

H_9: Top management support negatively mediates the relationship between complexity and 4IR technology adoption among SMEs.

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H_{10}: Top management support negatively mediates the relationship between cost and 4IR technology adoption among SMEs.

H_{11}: Top management support positively mediates the relationship between firm size and 4IR technology adoption among SMEs.

H_{12}: Top management support positively mediates the relationship between competitive pressure and 4IR technology adoption among SMEs.

H_{13}: Top management support positively mediates the relationship between government support and 4IR technology adoption among SMEs.

2.10 Summary

This chapter provided a detailed review of extant literature, focusing on factors that could affect the adoption of 4IR technologies within the context of SMEs. Based on the research background and problem statements presented in Chapter One, the study draws upon two underpinning theories: the DOI theory, and the TOE framework to produce the constructs and variables in the research framework. Miles and Snow (1978) strategy typology was the third underpinning theory used to profile the SMEs. The mediating effect of top management support on the relationship between factors of adoption and 4IR technology adoption was presented. The crux of empirical studies provided various definitions and concepts of study variables and constructs, as well as findings and contribution were developed. Following this, the study hypotheses were proposed. The next chapter explains in detail the research methodology to attain results for the study.

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CHAPTER THREE
RESEARCH METHODOLOGY

3.1 Introduction

This chapter explains and justifies the research methodology. Initially, the philosophy of the study will be presented. Next, the research design and research strategy employed in the study would explain the nature of the research; unit of analysis; sampling procedures; operationalizing variables and their measurements; data collection and techniques of data analysis. Finally, the chapter will conclude with a summary.

3.2 Research philosophy

It is important to understand reasons for conducting research. Subsequently, the following discussion will enlighten basic research philosophy concepts. The term 'research philosophy' refers to the perspectives or beliefs of reality that researchers use in approaching and executing a research (Al Isma'ili, 2017; Raddon, 2010). Saunders et al. (2023) depicted an onion Figure 3-1 as analogy to the stages of a research methodology. The researcher will 'peel' through the onion, layer by layer, constituting a research philosophy (also known as a research paradigm); research approach; research strategy; time frame; and finally, data collection and analysis.

There are various approaches of research philosophies, innovation and social science studies notwithstanding, namely ontology, epistemology, and axiology (Saunders et al., 2023). Epistemology constitutes valid knowledge and how to obtain it (Saunders et al., 2023). On the other hand, ontology was posited simply as phenomena or

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substance in the empirical world represented by concepts as they exist (Saunders et al., 2023).

Under these research philosophy, there are four main types of worldviews : positivism, interpretivism, postmodernism, and critical realism, pragmatism (Saunders et al., 2023). Interpretivist epistemology seeks to explain and understand in-depth phenomenon, with a view that experiences and expectations will result in multiple interpretations of reality (Joe F. Hair Jr. et al., 2020). On the other hand, positivist epistemology assumes that reality exists distinctly in facts and values, enabling an objective and value-free inquiry possible (Saunders et al., 2023). It is typified by hypotheses and/or research questions testing that originate from existing theory of knowledge and can be replicated by other researchers with similar quantifiable results through statistical analysis (Saunders et al., 2023). It is noteworthy to state here that Creswell (2014) uses the term 'postpositivism' instead of 'positivism'; boldly challenging the traditional notion of absolute truth of knowledge. Postpositivism signifies the thinking after positivism, in which the worldview recognizes researcher bias and allows theory refinement through interpretive insights (Creswell, 2014). This study adopts a positivist view as it treats constructs as measurable and independent of the researcher, and thus, enabling generalizable and replicable findings.

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3.3 Research approach

In order to conduct a social science research, a protocol or plan of theory and research has to be determined. According to Venkatesh et al. (2003), aspects of technology

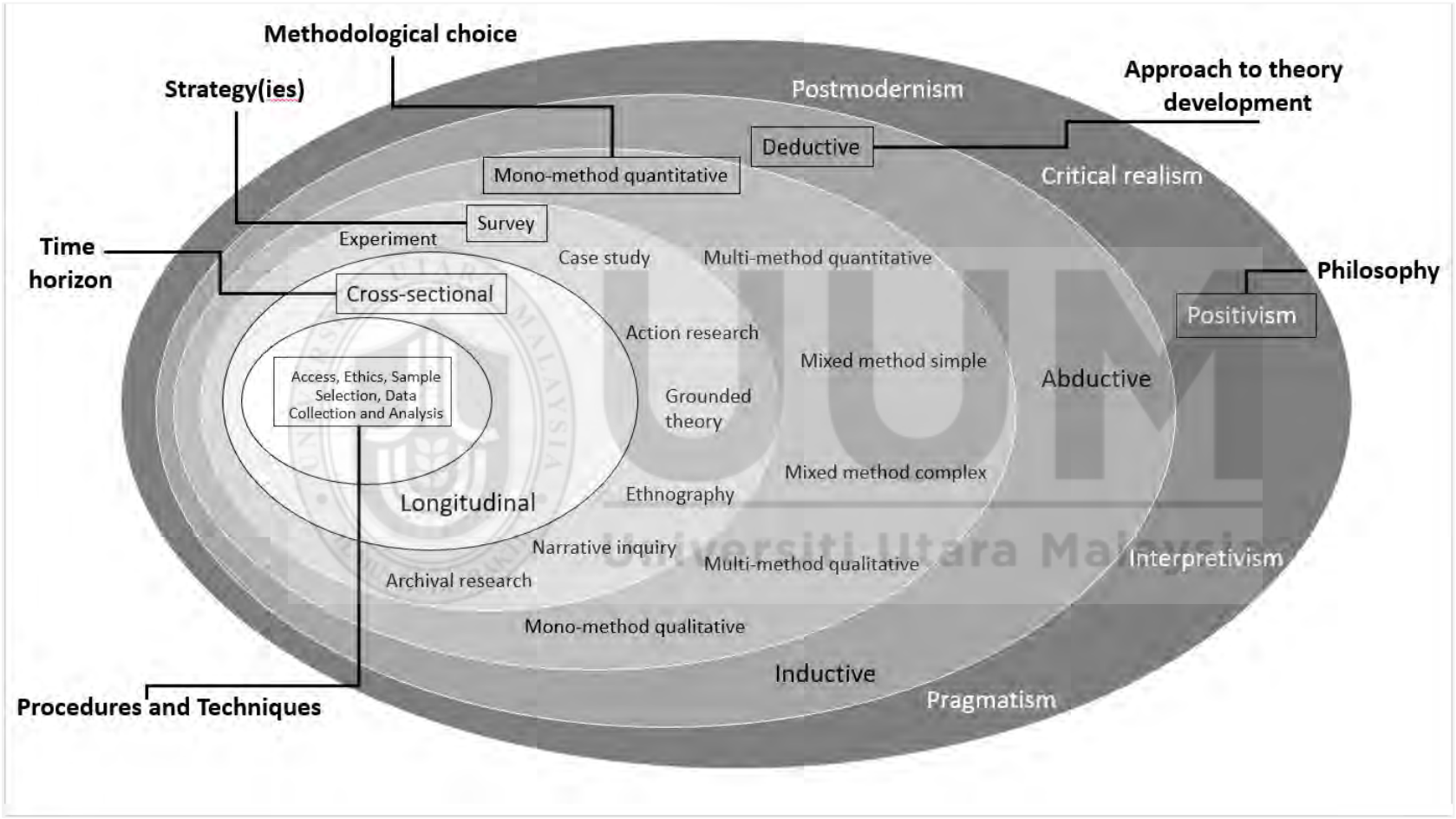


Figure 3-1
The Research Onion (Saunders et al., 2023)

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adoption have been studied widely in the information systems field, using a myriad of theoretical frameworks and models with identified constructs and variables. Building upon the next layer in the research onion is the nature of the study, namely, inductive or deductive (Saunders et al., 2023). In the case of a deductive approach, the research will utilize a theory as its theoretical framework to test the validity of posited hypotheses. In quantitative studies, one uses review of literature on a theory deductively and places it toward the beginning of the proposed study. The researcher then tests or verifies a theory by examining hypotheses or questions derived from it. (Creswell, 2014). On the other hand, an inductive research begins with building data into themes and ends with a generalized theory or model (Creswell, 2014), which is used in qualitative studies. Moreover, the inductive approach shall not entail any hypothesis formulation (Creswell, 2014).

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In line with this and the chosen positivism epistemology philosophy, the approach taken by this research is deductive in nature or hypothesis testing. Consequently, the study is conducted using quantitative method, which refers to a social inquiry that adapts empirical and statistical methods (Cohen, 1988). It originates mainly from the psychology field (Creswell, 2014) and thereby focuses on issues of data and measurement rather than semantics and meaning (Goertz & Mahoney, 2012). Additionally, the dominant method used in adoption research is the survey method based on a study that reviewed literature by (L. Chen & Holsapple, 2013). Thus, the research approach for this study is quantitative, decided based on reasons stated henceforth. The variables used in the study has been identified and analyzed in prior empirical research. Moreover, the variables in this study are derived from existing theories and models through the development of hypotheses. Finally, latent variables

are operationalized into measurable and observable dimensions quantitatively, with the researcher being objective on the research topic.

3.4 Research strategy

According to Yin (1994), various research strategies can be utilized in social science research, including archival analysis, case study, experiment, history and survey. Researchers must decide on the most suitable research strategy depending on the nature and requirements of the study (Yin, 1994). A review of literature on e-business adoption conducted by Chen & Holsapple (2013) concluded that out of 219 studies on business organizations, 71.2 percent used quantitative method, whereas 63.5 percent used survey. To this end, this study uses quantitative method via survey to study 4IR technology adoption by SMEs, to enable better generalization of findings more effectively.

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3.5 Research design

The fourth layer of the research onion entails the strategy or research design for the study, which must be consistent with the choice of research philosophy and research approach (Saunders et al., 2023). A research design is concerned with a strategic framework detailing specific procedures and methods of data collection; selection of respondents; and instruments used in collecting data. In this regard, the ensuing sections will discuss the final two layers of the research onion (Saunders et al., 2023) the nature of study, unit analysis, sampling procedures, instrumentation, data collection procedure, data analysis methods to test the hypotheses, and finally, measurement of variables.

According to Creswell & Creswell (2018), each type of research design inquiry, whether it is quantitative, qualitative or mixed methods, will dictate specific direction for procedures. Quantitative approach is advantageous for theory testing or development, determine integral variables for further research as well as relevant variables through the use of standards validity and reliability and statistical procedures (Creswell & Creswell, 2018) and appropriate for a positivist paradigm. It is most effective for social science field, as well as multidisciplinary research (Pickering & Byrne, 2014).

3.5.1 Nature of the study

Researchers have classified business research into three types of research designs depending on its nature, namely explanatory, exploratory, descriptive, and causal design (Bougie & Sekaran, 2019). The first one, exploratory research typically uses a qualitative method to study a topic wherein the variables and theory base are unknown (Creswell & Creswell, 2018). The second type of research is descriptive, which is useful to accurately depict the profile of an organization, respondents, situations, or events (Bougie & Sekaran, 2019) with some level of understanding of the problem. The third and final type is causal or hypothesis research allows description concerning the nature of relationships among variables and can conclude causality between the variables examined (Bougie & Sekaran, 2019). Since this study focuses on the correlations and hypotheses among TOE factors and 4IR technology adoption, as well as broadly among SMEs in manufacturing and service sectors, the nature of the study is causal and predictive.

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3.5.2 Study population

In this study, the population studied in the SMEs in Malaysia. Globally, formal SMEs represent about 90 percent of business establishments (World Bank Group, 2020), whereas in Malaysia, SMEs consists of 96.9 percent of all business enterprises or a total of 1,101,725 SMEs (Department of Statistics Malaysia, 2024a). Since the research focuses only on SMEs categorized as small and medium in the manufacturing and service sectors, the total population of the study totals 229,083 enterprises (Department of Statistics Malaysia, 2024a) as in Table 3-1. To this end, the researcher obtained the research databases of Malaysian SMEs from DOSM and the Malaysian Productivity Centre (MPC), covering specifically two types of enterprises (small and medium) from two macroeconomic sectors (manufacturing and service).

Table 3-1
Small and medium establishments in Malaysia in manufacturing and service sectors

SECTOR	Number of SME Establishments		TOTAL
	Small	Medium	
Services	184,128	15,444	199,572
Manufacturing	27,162	2,349	29,511
TOTAL	**211,290**	**17,793**	**229,083**

Source: Economic Census 2024: Profile of Small and Medium Enterprises (reference year 2015), DOSM.

3.5.3 Sample size

Prior to applying a sampling frame, the sample size has to be determined. The researcher decided to utilize G*power calculator to calculate the sample size. Based on a 0.15 effect size (f^2), margin of error alpha (α) value of 0.05, power at 0.80, and 7 predictors, a minimum sample size of 103 SMEs was calculated (Appendix C). There

is a prevalence of low response rate trend among SMEs as evidenced by previous studies, i.e. 4.7 percent response rate to survey questionnaire conducted by Raja et al. (2016) and 12.67 percent by Omar (2018) in Malaysia; 10 percent in the USA (Gunasekaran et al., 2011); and 9.9 percent in Taiwan (Y. Y. K. Chen et al., 2016). Assuming a conservative average response rate of 8.67 percent among Malaysian SME studies (at 4.67 percent and 12.67 percent by Raja (2016) and Omar (2018), respectively), at least 1,324 emails need to be sent out to achieve the minimum sample size of 103 responses.

Sampling is the process of selecting a sufficient number of the right elements from the population such that it is possible to generalize those properties or characteristics to the population (Bougie & Sekaran, 2019). Considering the trend of low response rates among SMEs, typically outdated email addresses in databases as they are easier to change compared to physical addresses (Stedman et al., 2019), as well as the fact that Malaysian managers are typically more averse to participate in surveys (Jusoh & Parnell, 2008), oversampling is recommended by scholars such as Salkind (1997). These scholars advocated increasing the sample size by 40 to 50 percent more to hedge against low response rate or unusable responses. Ultimately, with a 50 percent oversampling (Salkind, 1997), the final sample size in this research was calculated to be 1,986 SMEs.

The database obtained from DOSM was originally 15,000 SMEs, but after checking for current establishment status to exclude wound down companies and redundancies within the DOSM database, as well as with the MPC database, 9,660 remained. As for the MPC database, originally there were 6,287 SMEs but after screening those

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companies with no available email address, non-SMEs, and redundancies with DOSM database, it is left with 5,610 SMEs. After the clean-up was completed, the combined database totaled 15,270 SMEs.

3.5.4 Sampling frame

A sampling frame is then applied to this research database. A sampling frame is simply a list to draw a sample from which ultimately leads to the sample units from which the study can obtain information (Bougie & Sekaran, 2019). In this study, a form of random sampling called systematic sampling was applied. The scope of the study encompasses two types of SMEs (small- and medium-sized) as well as two macroeconomic sectors (manufacturing and services). However, given the SME composition in the databases obtained, which is not proportionate to the types of SMEs, stratified sampling method was not a plausible option. Systematic sampling is a population sampling method for statistical inference (Joe F. Hair Jr. et al., 2020). To perform this type of sampling frame, a sample size must be decided. As per the sample size calculation done in section 3.5.3 Sample size, a total of 1,986 SMEs will be sampled from the research database. To determine the interval at which to apply the systematic sampling, the 15,270 SMEs were numbered consecutively, and then divided by the target sample size of 1,986. This resulted in selecting SMEs at intervals of seven, yielding a pool of 2,181 company emails from the research database. Nevertheless, only 1,986 emails in total were sent and the balance of 195 SMEs were reserved as replacements.

3.5.5 Unit of analysis

It is critical to decide which unit of analysis will be applied in a study as the impact of technology adoption or innovation would differ according to the population studied. For example, technology adoption at the level of users of mobile applications would differ greatly from a manufacturer (Abdullah et al., 2019; L. Chen & Holsapple, 2013). Tornatzky & Fleischer (1990) discussed at length six possible unit of analysis as follows: individuals as individuals; individuals enacting social roles; social groups; organizations; interorganizational links; aggregates of organizations (for example, industries); and societies. Organization is more prevalent as unit of analysis for studying adoption and diffusion of technological innovation (L. Chen & Holsapple, 2013). The unit of analysis chosen for this study is organization.

3.6 Data collection procedures

Researches usually employ questionnaires as it can reach a large number of respondents and more economical to be administered (Bougie & Sekaran, 2019). There are numerous methods to administer a questionnaire either electronically or manually. To electronically distribute a questionnaire that is designed using a survey software, its hyperlink can be circulated via email, on social media platforms, or a website. Alternatively, to do it manually, a questionnaire can be printed and distributed face-to-face at appropriate venues; inserted in magazines, periodicals, or newspapers; or by mailing a questionnaire directly to respondents (Joe F. Hair Jr. et al., 2020). Notwithstanding these options, electronic form of questionnaire or email have now become standard, as it offers a simple, fast and less costly method to gather data and circumvent missing responses, ease of data entry and minimize human error (AlSharji

et al., 2018). Moreover, since the target respondents in this research are geographically dispersed, the electronic approach will be more advantageous.

Considering the large and cross-sectional population studied, the instrument of choice for data collection is conducted via self-administered survey questionnaire, distributed electronically via e-mail or online web forms with a cover letter to respondents. As admitted by Bougie & Sekaran (2019) in their latest edition, even though the method of mailing self-administered questionnaires has long been the backbone of business research, the method has become outmoded by electronic methods. Furthermore, quantitative data collection via questionnaire is less time consuming and less costly compared to interview or observation methods (Bougie & Sekaran, 2019). Another benefit to the electronic means of responding to the questionnaire is its computerize nature, whereby respondents can go back and forth at their own pace (Bougie & Sekaran, 2019) and mandatory fields can be set so that the response given are complete, eliminating unusable responses.

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In order to ensure more accurate responses is by targeting the SMEs' decisionmakers such as chief executive officers (CEOs)/managing directors (MDs), C-suite levels (CEO minus one level), business owners and members of the senior management. It is important to ensure that the key respondents are among the decision makers because of these reasons: various constructs in the research framework require respondents from among those who are privy to the decision making process and oversee the entire business operations (Ghobakhloo et al., 2011); and as discussed in earlier sections, technology adoption entails a decision and allocation of resources (Fariborz Damanpour & Schneider, 2006).

3.7 Questionnaire design

This study employs a predominantly structured questionnaire with close-ended multiple questions referencing Likert's (1932) original scale that included five response options. The constructs in the research framework are measured using a five-point Likert-type interval scale ranging from the strongest negative on the left most side of the scale as 1, to the strongest positive on the right most side as 5. Meanwhile, the latent variable is measured using a subjective five-point interval scale. An interval scale is deemed the most appropriate in adoption studies as adoption is based on perceptions (Tornatzky & Klein, 1982). The five-point scale was deemed optimal, in line with empirical studies that found respondents preferring shorter scales which are fairly quick to use (Preston & Colman, 2000; Taherdoost, 2019), as well as taking into consideration the degree to which a respondent can potentially discriminate along a longer scale (Simms et al., 2019). A PRISMA method systematic literature review conducted by Kusmaryono et al. (2022) found that 90 percent of 60 articles reviewed overwhelmingly used Likert-type scale with odd-numbered response options.

Moreover, prior studies similar to this research show good reliability scores (Alsharari et al., 2020; Hoque et al., 2016; D. Kumar et al., 2017b; Mohtaramzadeh et al., 2018) Aside from these questions, screening questions for demographic nominal data will be applied in this survey, particularly about the position and qualification held by the respondent, details about their tenure at the company, as well as details about the profile of the company itself. Questions pertaining to the number of full-time employees, annual turnover and the economic sector (manufacturing or service) were included to identify and ensure only small- and medium-sized companies, according to NSDC definition, participate in the survey.

Finally, the strategy typology profile of the respondent SMEs will be measured using a nominal scale to determine its archetype. Overall, in designing the questionnaire, the researcher was cognizant about reducing common method biases. Thus, the questionnaire was developed by employing different scale formats and scale anchors, as well as obtained measurement items from different sources for criterion and predictor variables (Podsakoff et al., 2003).

Following the discussions above, this study's questionnaire is divided into five major parts comprising seven sections. Section one collects demographic data about the respondent; section two measures the strategy typology of the organization; section three collects profile data about the organization; sections four through six measures the technology, organizational and environmental dimensions; and lastly, section seven measures the dependent variable 4IR technology adoption.

The final questionnaire contains thirteen pages, with a total of 72 questions in Malay and English languages (Appendix A and B) created using online software MOAform, developed and serviced by Qoom Networks, Inc. Respondents were offered two separate hyperlinks to choose from, and self-select their preferred language version. MOAform was selected as an alternative to Google Form because of its functional superiority even with the free version. Advantages of MOAform includes its advanced functions for question types (e.g., scoring, file upload, logic jumps), better display on various screen sizes, advanced logic and branching (show/hide, jump to page, end logic) capabilities, and data export options into Excel or CSV format to allow better data analysis using Excel instead of Google Sheets.

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3.8 Instrument development and measurement of variables

Adaptation of measurements from prior studies was necessary to operationalize constructs in this exploratory research framework. The research consists of three main independent variables as the influencing factors involving a total of seven dimensions, namely relative advantage (RA), complexity (CPLX) and cost of implementation (COST) under the technological context; top management support (MGMT), and size of the firm (SIZE) under organizational context; and finally, government support (GOVT), and competitive pressure (COMP) under the environmental context. All these independent variables are measured using Likert-type scale, whereby each point was labelled as: 1-Strongly Disagree, 2-Disagree, 3-Neutral, 4-Agree and finally 5-Strongly Agree.

The dependent variable, 4IR technology adoption, is measured using a five-point subjective rating scale as approached by Chwelos et al. (2001) to maintain consistency with the independent variables, instead of a binary variable which is commonly used in adoption studies (Thiesse et al., 2011). Moreover, the multi-item measurement approach used by Chwelos et al. (2001) is most appropriate for this research which also studies organizations that are also in the process of adopting new technologies. Chwelos et al. (2001) developed their model using case studies by Iacovou et al. (1995) amalgamated based on factors from a substantial stream of research. Their model incorporated constructs found to be influential in prior literature that were then categorized into essentially technological, organizational and interorganizational foci of EDI adoption. Finally, to assess the SME's strategy typology profile, a self-typing multi-item nominal scale consisting of 11 items adapted from Conant et al. (1990) is

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Table 3-2

Measurement Sources for Structuring Survey Questionnaire

Type of construct/variable	Constructs/Dimension	Sources	Number of items	Cronbach's α
Dependent variable	**Adoption of 4IR Technologies**	Thiesse et al. (2011) Abu Bakar et al. (2020)	5	0.86 to 0.97
Independent variable	**Technological Factor** - relative advantage - complexity - cost	 Maroufkhani, Tseng, et al. (2020) Thiesse et al. (2011) Thiesse et al. (2011)	 6 3 5	 0.85 to 0.89 0.79 to 0.83 0.80 to 0.96
Independent variable	**Organizational Factor** - top management support - size of firm	 Soliman & Janz (2004) Ali et al. (2020)	 4 3	 0.928 to 0.965 0.79-0.86
Independent variable	**Environmental Factor** - government support - competitive pressure	Alkisher (2013); Lin Li (2001), Oliveira et al. (2014) Thong & Yap (1995), Ifinedo (2011)	6 8	0.921-0.958 0.721-0.715
Strategy Profile	**# Firm Strategy Typology** - *Prospector* - *Defender* - *Analyzer* - *Reactor*	Conant et al. (1990)	11	0.56-0.82

Not part of the instrument in a multi-item scale for measuring strategic types (Conant et al., 1990)

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used to identify the archetypes for defender, prospector, analyzer and reactor (Conant et al., 1990; Parnell et al., 2015; Snow & Hambrick, 1980).

Table 3-2 lists instrument items drawn from prior studies based on their respective Cronbach's alpha (α) values to formulate the main survey questions to be adapted in this study. The α value ranging from 0.7 and above are deemed to be adequate to indicate convergence or internal consistency reliability (Joe F. Hair Jr. et al., 2017). Even so, a minimum α of 0.6 is still acceptable (Bougie & Sekaran, 2019).

3.8.1 Instrument development for measuring Relative Advantage

Relative advantage refers to the potential direct and indirect benefits from adopting 4IR technologies in terms of economic profitability being better compared to the supplanted technologies (Rogers, 1995). The economic profitability may include cost savings, opening up new markets or business opportunities, improving productivity and customer service through enhanced control and informed decision-making (Maroufkhani, Tseng, et al., 2020). Cronbach's alpha for similar items recorded in prior studies ranged between 0.85 to 0.89 (Chatterjee et al., 2021; Ilin et al., 2017; Maroufkhani, Tseng, et al., 2020; Skafi et al., 2020). The following Table 3-3 presents a total of six items use in measuring relative advantage in the study.

Table 3-3
Instrument for measuring variable: Relative Advantage

A1. 4IR technology improves our company's quality of work	(Maroufkhani, Tseng, et al., 2020)
A2. 4IR technology makes our work more efficient.	
A3. 4IR technology lowers our costs of doing business.	

Table 3-4
Instrument for measuring variable: Relative Advantage (continued)

A4. 4IR technology improves our customer service.	(Maroufkhani, Tseng, et al., 2020)
A5. 4IR technology attracts new sales to new customers or new markets to our company.	
A6. 4IR technology identifies new product/ service opportunities for our company.	

3.8.2 Instrument development for measuring Complexity

Complexity is the degree to which 4IR technologies are perceived as being relatively difficult to understand and use (Thiesse et al., (2011). Cronbach's alpha for similar items recorded in prior studies ranged between 0.79 to 0.83 (Chatterjee et al., 2021; Ilin et al., 2017; Maroufkhani, Tseng, et al., 2020; Skafi et al., 2020). Table 3-5 presents a total of six items used in measuring complexity in the study.

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Table 3-5
Instrument for measuring variable: Complexity

B1. The skills necessary to use 4IR technology are too complex for our employees.	Thiesse et al. (2011)
B2. The skills needed to implement 4IR technology are too complex for our company.	
B3. Integrating 4IR technology into our current work practices will pose a challenge.	

3.8.3 Instrument development for measuring Cost

The final technological factor is another one that impedes the adoption of 4IR technology. Cost in this study refers to the cost of implementation of 4IR technologies, which includes acquisition and maintenance costs, training of employees, necessary costs of business process improvement, and even the opportunity costs when replacing a legacy technology as a result of 4IR technology adoption. In the SLR conducted by Ahmad et al. (2020) COST (cost of implementation) was listed as the top five out of 93 determinants of business intelligence systems (BIS) adoption studied between 2011 and 2020. Table 3-6 presents the adopted items used to measure cost in the study.

Table 3-6
Instrument for measuring variable: Cost

C1. The most important factor for our company is the low acquisition costs of 4IR technology.	Thiesse et al. (2011)
C2. The costs for training employees to use 4IR technology are very high.	
C3. The costs for business process improvement in terms of 4IR technology adoption are very high.	
C4. The costs of maintaining 4IR technologies will be prohibitively high.	
C5. The costs of implementing 4IR technologies for our suppliers will be high.	

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3.8.4 Instrument for measuring Firm Size

Table 3-7 presents the adopted items used to measure firm size in the study.

Table 3-7
Instrument for measuring variable: Firm Size

E1. In our opinion, small organizations are more flexible in adopting 4IR technologies.	Ali et al. (2020)
E2. In our opinion, larger organizations are more flexible in adopting 4IR technologies.	
E3. The number of employees in our company is high compared to others in the industry.	
E4. Our annual sales turnover is high compared to others in the industry.	

3.8.5 Instrument development for measuring Top Management Support

Table 3-8 presents the adopted items used to measure top management support in the study which is both a mediator variable and an independent variable.

Table 3-8
Instrument for measuring variable: Top Management Support

D1. Our top management is likely to invest funds in 4IR technology adoption.	Soliman & Janz (2004)
D2. Our top management is willing to take risks in adopting 4IR technologies.	
D3. Our top management is likely to be interested in 4IR technology adoption in order to gain a competitive advantage.	
D4. Our top management is likely to consider 4IR technology adoption as strategically important.	

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3.8.6 Instrument development for measuring Competitive Pressure

Table 3-9 presents the adopted items used to measure competitive pressure in the study.

Table 3-9
Instrument for measuring variable: Competitive Pressure

F1. Our customers can easily switch to another company for similar products/ services.	Thong & Yap (1995), Ifinedo (2011)
F2. Our customers are able to easily access several existing products/ services which are different from ours but perform the same functions.	
F3. There is intense rivalry among companies in the industry in terms of 4IR technology adoption.	Thong & Yap (1995), Ifinedo (2011)
F4. Some of our competitors have already started using 4IR technologies.	
F5. Our company is under pressure from customers to adopt 4IR technology.	
F6. Our company is under pressure from competitors to adopt 4IR technology.	
F7. Our company is under pressure from suppliers to adopt 4IR technology.	
F8. Our company is under pressure from our partners to adopt 4IR technology.	

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3.8.7 Instrument development for measuring Government Support

Table 3-10 presents the adopted items used to measure government support in the study.

Table 3-10
Instrument for measuring variable: Government Support

G1. The Government policies provide effective initiatives to promote our company to adopt 4IR technologies.	Alkisher (2013); Lin Li (2001) Oliveira et al. (2014)
G2. The Government provides education and training programs related personnel to motivate our company to adopt 4IR technologies.	
G3. The Government provides financial incentives (e.g. funds, grants, subsidies etc.) to encourage our company to adopt 4IR technologies.	
G4. These financial incentives (e.g. funds, grants, subsidies etc.) are processed promptly enough for our company to adopt 4IR technologies.	
G5. The Government agencies monitor our company's commitment to adopt 4IR technologies.	
G6. The Government actively supports the adoption of 4IR technologies by the industry.	

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3.8.8 Instrument development for measuring Adoption of 4IR

The dependent or criterion variable for this study is 4IR technology adoption. Table 3-11 presents the adopted items used to measure 4IR technology adoption in the study. Instead of a singular item measuring the 4IR adoption using nominal scale with binary values that are common in adoption studies (AL-Shboul, 2019; Skafi et al., 2020; Thiesse et al., 2011), the researcher decided to adapt five items to measure using subjective scale (Abu Bakar et al., 2020; Thiesse et al., 2011) with a score ranging from 1 to 5 as follows:

Table 3-11
Instrument for measuring dependent variable 4IR technology adoption

Measurement Item for 4IR technology adoption	**Source(s)**
1. 4IR technology adoption for our company is currently at: • Have already adopted services, infrastructure, or platforms of 4IR technologies. • Currently evaluating implementation (e.g., in a pilot study). • Have evaluated and are planning to adopt 4IR technologies. • Have evaluated but decided NOT to adopt 4IR technologies. • Not considering at all.	Thiesse et al. (2011)

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Measurement Item for 4IR technology adoption	Source(s)
2. If our company has adopted/will adopt (more) 4IR technologies in the future, it is expected to happen (when): • Not adopting • In less than 1 year • Between 1 and 2 years • Between 2 and 5 years • More than 5 years	

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Table 3-12
Instrument for measuring dependent variable 4IR technology adoption (continued)

3. The number of 4IR technologies have been/will be adopted by our company: • More than 6 types • Between 4 to 5 types • Between 2 to 3 types • 1 type • None	Abu Bakar et al. (2020)
4. Our company's frequency usage levels when applying adopted 4IR technology towards any related job: • Used Extensively • Used Frequently • Used Quite Often • Used Rarely • Not Used At All	
5. Total time spent by our company in a day using the adopted 4IR technology for any related jobs: • All the time • 5 to 7 hours daily • 2 to 4 hours daily • Less than two hours daily • Not used at all	

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3.8.9 Instrument development for assessing strategy typology

It is important to identify a company's strategic type as it would shed light on top management support in digital transformation. As part of the profiling exercise to assess SMEs' categorical strategy typology construct, Conant et al.'s (1990) self-

typing measurement approach using multi-item close-ended scale, complemented by investigator-specified decision rules in the case of ties, were adapted. The multi-item scale relate to the adaptive cycle of entrepreneurial, engineering and administrative components of Miles and Snow's (1978) adaptive cycle and how top management responds to them strategically. There were eleven dimensions explicated in this adaptive cycle, followed by four distinct response options for each question, conceptually anchored to all four strategic groups Defender, Prospector, Analyzer, or Reactor.

Respondents are asked to choose only one of the four statements under each question that would best describe their company. Subsequently, each company goes through a categorization analysis based on a majority-rule decision structure, depending on the archetypal response option selected most often. The company's strategy typology is then categorized as either Defender, Prospector, Analyzer, or Reactor, unless in the case of ties. In essence, ties between two or more categories excluding Reactor would result in the SME being categorized as an Analyzer while any ties encompassing Reactor typology would result in the SME being categorized as a Reactor. These decision rules are also theoretically anchored in Miles and Snow's (1978) original conceptualization of the four strategy typologies, in which Analyzers are a hybrid between Defender and Prospector characteristics whereas Reactors react incoherently to the challenges of the adaptive cycle as Defender, Prospector or Analyzer at different times. The reliability coefficient, Cronbach's alpha, ranged between 0.56 and 0.82, with a mean of 0.69 (Conant et al., 1990), which is above the acceptable minimum α of 0.6 (Bougie & Sekaran, 2019). Table 3-13 presents the adapted items used to categorize strategy typology in the study.

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Table 3-13
Self-typing Approach for Categorizing Strategy Typology

I. Entrepreneurial Domain of the Adaptive Cycle

1. In contrast to the competitors, our image in the market is that we:

- Reacts to opportunities or threats in the market to maintain or enhance our position. (R)
- Have a reputation for being innovative and creative. (P)
- Adopt new ideas and innovations, but only after careful analysis. (A)
- Offer fewer, selective products/services but are high in quality. (D)

2. The amount of time and resources our company spends on monitoring changes and trends in the market can best be described as:

- Lengthy: we continuously monitor the market. (P)
- Average: we spend a reasonable amount of time monitoring the market.(A)
- Minimal: we hardly spend much time monitoring the market.(D)
- Sporadic: we sometimes spend a great deal of time but at other times we spend little time monitoring the market.(R)

3. In comparison to the competitors, the products/services we provide to our customers are:

- Well focused, stable, and consistent throughout the company and the markets. (D)
- Fairly stable (i.e. unchanged) in several units/departments/markets but innovative in others. (A)
- More innovative, continually changing, and broader in nature. (P)
- In a state of transition, and largely based on responding to opportunities or threats from the market or environment. (R)

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Table 3-11
Self-typing Approach for Categorizing Strategy Typology (continued)

I. Entrepreneurial Domain of the Adaptive Cycle (continued)
4. Compared to other companies, the increases or losses in demand for our products/services is mainly due to our practice of: • Concentrating more on fully developing the markets that we currently serve. (D) • Assertively penetrating deeper into the markets that we currently serve, but also adopting new products/services after a very careful review of their potential.(A) • Aggressively entering new markets with new products/services.(P) • Responding to the pressures of the market by taking minimal risks.(R)
II. Engineering Domain of the Adaptive Cycle
5. One of the most important goals in this company is our dedication and commitment to: • Ensure that people, resources & equipment required to develop new products/services and enter new markets are available and accessible. (P) • Carefully analyze costs in revenue to keep it under control & selectively develop new products/services or enter new markets.(A) • Keep costs under control. (D) • Ensure we guard against critical threats by taking any actions necessary.(R) **6.** Compared to other companies, the competencies (skills) of our management can be best characterized as: • Fluid: their skills are related to the short-term demands of the market. (R) • Broad and entrepreneurial: their skills are diverse, flexible, and enable change. (P) • Analytical: their skills enable them to both identify trends and then develop new product/service offerings or markets. (A) • Specialized: their skills are concentrated into one, or a few, specific areas.(D)

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Table 3-11
Self-typing Approach for Categorizing Strategy Typology (continued)

II. Engineering Domain of the Adaptive Cycle (continued)
7. The one thing that protects our company from competitors is that we are able to: • Do a limited number of things exceptionally well. (D) • Carefully analyze emerging trends and adopt only those with proven potential. (A) • Consistently develop new products/services and new markets.(P) • Respond to trends although they may have only moderate potential of happening. (R)
III. Administrative Domain of the Adaptive Cycle
8. Compared to other companies, our management staff tends to focus on: • Developing new products/services and expanding into new markets or market segments. (P) • Analyzing opportunities in the market and selecting only those opportunities with proven potential, while protecting a secure financial position.(A) • Maintaining a secure financial position through cost and quality control measures.(D) • Activities or business functions which most need attention given the opportunities or problems we are currently facing.(R) **9.** Compared to other companies, we prepare for the future by identifying: • the best possible solutions to problems or challenges that require immediate attention.(R) • trends and opportunities which can result in the creation of product/service offerings that are new to the industry or can reach new markets.(P) • industry trends that our competitors have proven to possess long-term potential, while solving problems related to our current product/service offerings and our customer needs.(A) • problems which, if solved, will maintain, and then improve our current product/service offerings and market position.(D)

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Table 3-11
Self-typing Approach for Categorizing Strategy Typology (continued)

III. Administrative Domain of the Adaptive Cycle (continued)
10. Compared to our competitors, the organization structure of our company is: • Functional in nature (i.e. By department – marketing, accounting, etc.). (D) • A hybrid structure (i.e. Mainly functional in nature, but for newer or larger product/service offering areas, categories of product /service or market-oriented). (A) • Based on categories of product/service or market-oriented. (P) • Continually changing to enable us to meet opportunities and solve problems as they arise.(R)
11. The procedures our company uses to evaluate performance are best described as: • Decentralized and participatory; encouraging many organizational members to be involved.(P) • Hybrid; centralized in more established product/service areas, and more participatory in newer product or service areas.(A) • Highly centralized and primarily the responsibility of senior management.(D) • Heavily oriented towards those reporting requirements which are urgent.(R)
Legend: (D) = Defender, (P) = Prospector, (A) = Anayzer and (R) = Reactor. Not part of the instrument and only for informational purposes.

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3.9 Pretest Study

The next stage is to check the validity of the designed questionnaire. There are two parts to the questionnaire validation process; first, a pretest to test face validity and content validity of the questionnaire; and second, a pilot study. Hair et al. (2020, p. 296) asserts that a questionnaire should only be administered after the expected consistency and accuracy of responses are assessed by the researcher. A pretest is a

mini survey administered to gather information from respondents who are similar in characteristics to the target respondents of the actual study. It serves to gauge if the researcher's chosen approach or method will carry out according to expectations (Joe F. Hair Jr. et al., 2020). Moreover, it provides the research an opportunity to reflect on their study and detect avoidable errors or any misunderstanding due to choice of words prior to commencing the full-scale study (Bougie & Sekaran, 2019).

According to Hair et al. (2020), for pretesting purposes, an appropriate range of sample size is between 4 to 20. For this study's questionnaire pretest for face validity, convenient sampling on a small group of 4 SMEs in Kuala Lumpur and Selangor states (2 SMEs in each state) are selected as respondents. These 4 companies will not be part of the final sample. Additionally, the pretest is also extended to 4 faculty members. The pretest will ensure that the instructions are clear and understandable; items in the instrument appear to be relevant, clear and easy to read, well-defined, and self-explanatory (Ghobakhloo et al., 2011; Oluwatayo, 2012). Based on the feedback and depending on the results of SEM analysis, the questionnaires are then examined, revised and fine-tuned and prior to commencing actual data collection.

The main objective in conducting the pretest is to determine the research instrument's reliability and validity, as well as to gauge the time needed to complete the questionnaire (Hair et al., 2020). Validity concept refers to the extent to which the instruments used in the study are validly measuring the constructs as they are intended to. The main concern of estimating the validity is to measure the appropriateness of the technique, instrument, and the study process (Hair et al., 2020; Sekaran and Bougie, 2019). Identify various names of establishing validity; However, the most

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common validity test used in many studies include construct validity, content validity, predictive validity, and face validity. Construct validity is vital for data analysis (Hair et al., 2020; Sekaran and Bougie, 2019).

Table 3-14
Face Validity Considerations During Pretest

Evaluated Factors	**Probing Questions**
Clearly worded sentences	Is there any part of any sentence that you find confusing? Is there any part of any sentence that you find difficult to comprehend? Is there any part of the questionnaire that you feel is difficult to understand? Are there any words that you do not understand? Are there any sentences that you are unsure of the meaning?
Ambiguous sentence	Do you clearly understand the online questions? Are there any questions that you do not clearly understand the meaning of? Based on each section do you clearly understand the focus of the questions? Are there any questions that you feel overlaid with another?
Scaling, formatting & instruction	Do you feel comfortable reading the questions in terms of clarity of the printed words? Is the font big enough? Do you clearly understand the scaling in relation to each question? Is the paging of each section convenient to read? Is the structuring of the questionnaire convenient to read and to answer?

Source: Author's own compilation

Face validity is a subjective judgment by a person taking a pretest to which a measure is related to a specific construct (Taherdoost, 2016). Since the study will be conducted

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in Malaysia whereby English is a second language, the questionnaire was translated into Malay language i.e. *Bahasa Melayu* by a certified translator. Hence, the pretest will involve a face validity exercise for both languages. This step is particularly important to ensure proper localization of the translated adapted measurement items but still matches closely to the original language. Respondents for the pretest need to assess the bilingual questionnaire with probing questions (as per Table 3-14) to gauge the quality of readability in both languages, clarity of questions, and word accuracy (McKay et al., 1996).

The second part of the pretest is to assess the questionnaire's content validity. In addition to the evaluated factors in face validity, selected experts are required to also evaluate the sufficiency and relevancy of items for concept measurement purposes of each construct and variable. The experts are asked to review each of the measurement item and circle a rating scale between 1 and 4 based on the degree of relevance and provide their comments about the item (Muda et al., 2020), as follows:

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Degree of relevance:

1 = the item is not relevant to the measured domain

2 = the item is somewhat relevant to the measured domain

3 = the item is quite relevant to the measured domain

4 = the item is highly relevant to the measured domain

Circle Rating 1 – 2 – 3 – 4	***4 – Perfect (maintain item as it is)***	***2-3 Moderate (maintain item with some refining)***	***1 – Poor (remove item)***
Rating/Comments			

Based on the individual feedback, the measurement items were refined accordingly. Their feedback was mainly on some wordings used, double-barreled questions. At the end, an optional, free-form section was included to gain explanations, comments or feedback about the factors included in the study, particularly to explain reasons for non-adoption. The data obtained from the free-form section was treated as qualitative, playing a supplementary role during hypothesis testing and discussion of findings.

3.10 Pilot Study

After the appropriate adjustments to the items in the questionnaire based on the pretest have been made, Hair et al. (2016) recommends that a pilot study be conducted. A pilot study is also known as a feasibility study; a dry run of the entire process of systematically administering survey questionnaire to ensure that the samples are diverse and includes all cross-section, and the process runs smoothly so that analysis and coding can be done with efficacy (Joseph F. Hair Jr. & Page, 2016). As a guideline, Hair et al. (2016) recommends a pilot study sample size of between 30 to 100, depending on the entire sample size. For the purposes of checking the internal consistency reliability using Cronbach's alpha (α) of the measurement items, a sample of 30 respondents is conventionally observed in a pilot study (Memon et al., 2017).

For this pilot study, cluster random sampling on a group of SMEs nationwide operating in manufacturing and service sectors are selected as respondents from a database provided by the MPC. The researcher used a self-completion approach to collecting data using structured questionnaires in bilingual (Malay and English) via e-mail, which contains a cover letter about the survey and a hyperlink to a Google Form for respondents to answer in. The decision to conduct the survey electronically was based

on a recent SLR article which found that 70 percent of surveys from 60 articles published between 2012-2021 were done online (Kusmaryono, 2022). The pilot was conducted via email to complete an online hyperlink to Google Form and took two months to complete, i.e. between December 2023 to February 2024. A total of 33 SME companies responded to the pilot study and will not be part of the final sample. Subsequently, the test for reliability and validity of the pilot data was conducted using SPSS 28 and presented.

3.11 Reliability and validity tests

The measurement items were adapted and adopted from previous empirical studies implemented by various scholars and researchers. Consequently, it is essential to test the reliability and validity of these items to confirm acceptability of the research findings as well as ensure that these items measured the variables used in this study as conceptualized. (Hair et al., 2016; Hair et al., 2020).

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3.11.1 Reliability

Reliability is the measure of internal consistency of the constructs used in the study. The construct is reliable if its alpha (α) value is greater than 0.70 (Joe F. Hair Jr. et al., 2020). For the pilot study, construct reliability was assessed using Cronbach's Alpha, whereas composite reliability will be used for the main study. To accomplish this, all the items under each construct were tested using reliability analysis using pilot study data. The reliability analysis results are based on relative advantage with five items; complexity with three items; cost with four items; firm size with three items; government support with 8 items; competitive pressure with six items; and finally, dependent variable, 4IR Adoption with 5 items, are summarized in Table 3-15:

Table 3-15
Reliability of the Instrument in the Pilot Study (n = 33)

Constructs	Number of Items	Cronbach's alpha (α)
relative advantage	6	0.892
complexity	3	0.937
cost	5	0.837
top management support	4	0.872
firm size • All items included • ***Item E2 omitted****	4 ***3***	0.488 ***0.753***
government support	6	0.922
competitive pressure	8	0.936
4IR Adoption	5	0.885

Note*: Firm size construct's measurement item E2. In our opinion, larger organizations are more flexible in adopting 4IR technologies.

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The latent variable firm size had a 0.488 Cronbach's alpha with 4 items, which is significantly lower than 0.500 i.e., the established threshold for internal consistency reliability (Cronbach's alpha) of 0.700. Since the α-value for firm size is less than 0.500, which is the cut-off value for a low indicator reliability (Joe F. Hair Jr. et al., 2020), item E2 is deleted. Based on this, the Item-Total Statistics (Table 3-15), firm size new Cronbach's alpha improved to 0.753. Hence, the main study will omit item E2 under firm size and it is now left with 3 items measurement items for firm size.

3.11.2 Validity

Validity concept refers to the extent to which the instruments used in the study are validly measuring the constructs as they are intended to. The main concern of estimating the validity is to measure the appropriateness of the technique, instrument, and the study process (Hair et al., 2020; Sekaran and Bougie, 2019). Scholars have identified a number of ways to establish validity, however, in the pretest stage, construct validity, content validity, and face validity were utilized. Subsequently, for the main study, construct validity, internal consistency, convergent validity and discriminant validity will be tested to evaluate the measurement model (Hair et al., 2020; Sekaran and Bougie, 2019).

3.12 Data analysis procedure

Prior to doing data analysis, preliminary steps such as coding the data, screening, cleaning, testing important assumptions (Osborne, 2013) and selecting an appropriate data analysis strategy, must be carried out (Bougie & Sekaran, 2019). Raw datasets must be coded appropriately to expediate statistical analysis. Data screening is imperative to ensure detection data errors that might influence the analysis, include activities such as straight-lining, missing data, normality.

Following the electronic questionnaire sent via email approach used in the pilot study, as well as the benefits from this approach, the main study was conducted similarly. The difference between the two questionnaires was the removal of item E2 from latent variable firm size, subsequent to the reliability test. Based on the response rate of 9 percent from past studies, and the minimum sample size using G*power calculator was 103 (Input parameters: 7 predictors, $\alpha = 0.05$, power = 0.80, effect size (medium),

f^2 = 0.15 as provided by Cohen (1988), as well as a precaution buffer of 50 percent (Salkind, 1997) a total of 1,717 emails should be sent out. Because the total usable responses in this study were 188, the study met the above requirement for further analysis.

In this study, data collected from the main survey will initially be edited, coded, and classified using the analyzed using Statistical Package for Social Sciences (SPSS) version 28 to perform data coding and screening, followed by a descriptive analysis of all the constructs, testing for straight-lining and multivariate outliers with HTMT. Data normality, multivariate skewness and kurtosis will be tested with Mardia's coefficient. Lastly, to assess the measurement model and the structural model, a PLS-SEM path modelling analysis is executed using SmartPLS 4 version 4.0.9.6. software, which is variance-based.

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3.12.1 Data coding

Responses received from conducted surveys must be coded preferably ahead of time by assigning a number to a particular response so that the answers can be keyed into a database (Joe F. Hair Jr. et al., 2020). Since this was an online questionnaire, the data did not need to be entered into a spreadsheet. However, questions with nominal or ordinal data, particularly the ones appearing in the demographic sections of the survey, require a coding exercise. In a quantitative study, coding involves the process of grouping non-numerical data into categories and then allocating a numerical code to each of the category. Another type of data that requires a coding approach is in such instances involving dummy variables, whereby one category is assigned a value of 1 and a zero to the other category. This will enable greater flexibility in data analysis

(Joe F. Hair Jr. et al., 2020). Some of the questions in the survey may require reverse coding and earmarked for recoding prior to data analysis.

3.12.2 Data screening

The initial data analysis process screened all possible errors such as missing data, or data entry errors. In addition, the study also performed a straight-lining and multivariate outlier tests. Straight-lining occurs when some respondents provide the same feedback or response for all or majority of the questions (Aarø et al., 2022). Scholars deem straight-lining as (Reuning & Plutzer, 2020). Straight-line responses are excluded as it compromises the integrity of the data (Yan, 2008). Outliers are an extreme response to a specific question, or to all of the questions in the survey (Joseph F. Hair Jr. et al., 2022); or data with values that lie outrange from the standard data (Zikmund et al., 2013). Sources of outliers could stem from an erroneous data entry exercise or an exceptionally high or low values that occur in reality (Joseph F. Hair Jr. et al., 2022). Data with outliers can affect the normality of the data, hence biased and affecting the results. Therefore, detecting the outliers on all independent and dependent variables is essential (Joseph F. Hair Jr. et al., 2022). Once identified, the outliers must be addressed by the researcher whether to be corrected in instances where there is a data entry errors, or perhaps retained in instances where the outlier represents an element of the population (Joseph F. Hair Jr. et al., 2022).

There exists a few methods of detecting outliers in data, either by using univariate, bivariate, or multivariate analysis. Since this study is a multivariate study, the researcher used SPSS Version 28 to run Mahalanobis Distance (D^2) to detect outliers (Joe F. Hair Jr. et al., 2020). Bivariate methods become inadequate mainly because

there are more than two variables involved, and therefore, to detect outliers using scatterplot involving for example, five variables, it would take 10 graphs for all pairwise comparisons (Joseph F. Hair Jr., Black, et al., 2019). On the other hand, the Mahalanobis D^2 method measures the distance between each observation and the multidimensional mean center of all observations. This method generates a single value D^2 for each observation, irrespective of the number of variables involved (Joseph F. Hair Jr., Black, et al., 2019). Outliers is identified in the dataset when p-value scored less than 0.05. The higher the D^2 value, the farther the observation is from the overall distribution in this multidimensional space (Joseph F. Hair Jr., Black, et al., 2019).

3.12.3 Descriptive Analysis

The descriptive analysis provides the frequency and percentage for the demographic profile of SMEs who responded in the survey, as well as the mean and standard deviation of all the variables involved. In addition, this analysis will inform and answer RO8, in profiling the strategy typology of the respondents. As mentioned earlier, this analysis will be executed using SPSS version 28 software.

3.12.4 Data analysis with PLS-SEM

The data analysis process is where the data gathered from the survey are statistically analyzed to determine whether the hypotheses posited earlier are supported (Bougie & Sekaran, 2019). In this study, the data collected for this research was analyzed using partial least squares (PLS), a variance-based structural equation modeling (SEM), using SmartPLS 4 software. PLS-SEM aims to maximize the explained variance of dependent variables (endogenous latent constructs). It is more appropriate compared to the covariance-based SEM (CB-SEM) as the study is a prediction-oriented and

theory development research involving multiple predictors and a mediator variable (Joseph F. Hair Jr., Risher, et al., 2019). Moreover, PLS-SEM method caters to complex models that may have data with distributional issues such as lack of normality, as well as the limitation in terms of being more tolerant towards smaller sample sizes such as in this study (Joseph F. Hair Jr., Risher, et al., 2019; Ramayah et al., 2018). It is evident that for prediction, theory development and even theory confirmation, PLS-SEM is increasing and extensively applied in various disciplines such as social science and information systems (Joseph F. Hair Jr., Risher, et al., 2019; Sabol et al., 2023). Nevertheless, scholars must continue to practice reporting sound reasons for using PLS-SEM while recognizing its broader relevance for exploratory and confirmatory research, alike (Sabol et al., 2023). Table 3-16 shows the consideration when choosing between partial-least squares SEM (PLS-SEM) and CB-SEM.

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Table 3-16
Decision factors in selecting SEM approach

Decision consideration	PLS-SEM	CB-SEM
Research goals	Prediction oriented	Parameter oriented
Model complexity	Large complexity (many constructs and many indicators).	Small to moderate complexity
Approach	Variance	Covariance
Assumption	Nonparametric	Parametric
Sample size	If the sample size is relatively low (Minimum of 20-100)	Large data sets (200 and above)

Source: (Joe F. Hair Jr. et al., 2017)

3.13 Testing of survey bias

The subsequent statistical tests are checked for normality and common method bias. Statistical assumption testing in multivariate analysis is crucial due to its characteristics that amplifies any potential biasness and distortions in a large data set

across a large number of variables. Moreover, multivariate analysis may masks violations of assumptions that exists in complex multivariate statistical analysis which is apparent in univariate analysis (Joseph F. Hair Jr., Black, et al., 2019).

3.13.1 Normality

Normality is the first assumption in a multivariate analysis. It simply means that the metric variables will be assessed using kurtosis and skewness, as well as normal probability plots (Joseph F. Hair Jr., Black, et al., 2019). According to proponents of partial least squares structured equation modelling (PLS-SEM), violations of normality is highly tolerated by this ordinary least square (OLS) regression-based method compared to maximum likelihood-based CB-SEM method (Chin, 2010; do Valle & Assaker, 2016; Nitzl, 2016; Nitzl & Chin, 2017). Nevertheless, distributional violations such as data containing extreme outliers or high measures of skewness and kurtosis in a multivariate model will exacerbate the bootstrapping standard error estimates. As a consequence, it would undermine the statistical estimation of the path coefficient (Hair et al., 2011; Joseph F. Hair Jr., Black, et al., 2019). Currently, many scholars (Hair et al., 2022; Sarstedt et al., 2022) strongly recommend researchers utilizing PLS-SEM to examine two measures of distributions, namely skewness and kurtosis, to determine the extent to which the data is non-normal. In this study, Mardia's coefficient will be applied to determine the data's multivariate normality, with values of multivariate skewness and multivariate kurtosis of less than ±3 and ±20, respectively.

3.13.2 Common method bias

Subsequently, another assumption tested is the common method bias (CMB). Scholars of social sciences disciplines discuss considerably about CMB a significant and substantial biasness presented by common methods variance (CMV) as a causal factor (Fuller et al., 2016). CMV defined as a systematic error variance introduced into a survey, either through the measurement methods or the measurement scale due to single source (respondent) data collection, when independent and dependent variables are answered together by a single person (Joe F. Hair Jr. et al., 2020; Podsakoff et al., 2003). Only when CMV affects the relationship between measured variables as well as introduces biasness, it follows that CMB is present. Scholars have developed a few techniques to minimize it procedurally, and measure it statistically on a post hoc basis. The study has incorporated some techniques procedurally by alternating the types of scales (single and multiple answers for nominal and ordinal scales; and 5-point Likert-type scale) and placements of different sections for the respondent profile, strategy typology profiling, exogenous and mediator variables, firm size and industry profiling, and lastly, the endogenous variable.

There are a number of statistical collinearity tests suggested by scholars, such as Harman's Single factor test (Podsakoff et al., 2003), marker variable technique (Lindell & Whitney, 2001) and full collinearity assessment approach (Kock, 2015; Kock & Lynn, 2012). In this study, the full collinearity assessment approach will be applied post hoc using PLS-SEM analysis. To check for CMB, the variance inflation factor (VIF) threshold is ≤ 3.3 as recommended by Kock & Lynn (2012) or ≤ 5.0 by Kock (2015). If the full collinearity test produced VIF values equal to or below either 3.3 or 5.0, the model is deemed to be free of CMB.

3.14 Measurement of model assessment

Construct validity is to ascertain whether a set of measurement items reflect the latent construct they are designed to measure. The construct validity in measurement model assessment means evaluating an indicator or item's validity and reliability (Ramayah et al., 2018). There exist two kinds of measurement model assessments, namely exploratory factor analysis (EFA) and confirmatory factor analysis (CFA). Between these two methods, the more applicable CFA measurement model assessment will be used. CFA will be used to confirm this study's measurement theory whereby it tests how well a priori theoretical pattern of factor as well as the measured variables represent latent constructs based on a theoretical specification (Ramayah et al., 2018). To this end, reflective measurement model assessment which consists of internal consistency reliability, convergent validity and discriminant validity tests will be discussed (Table 3-17).

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3.14.1 Convergent validity

Foremost, the first method in the reflective measurement model, convergent validity, assesses to what extent two measurement items of the same construct are correlated. High correlations indicate that the items are measuring the construct as intended (Joseph F. Hair Jr., Black, et al., 2019). For convergent validity, there are two criteria to look at: outer loadings of equal to or more than 0.5 is sufficient (Ramayah et al., 2018), even though Hair et al. (2019) recommended 0.708; as well as an average variance extracted (AVE) value of equal to or more than 0.5 (Joseph F. Hair, Black, et al., 2019; Ramayah et al., 2018).

Table 3-17

Summary of Indices for Reflective Measurement Model Analysis Using PLS-SEM

	Validity Type	**Criterion**	**Guidelines**
1	Internal consistency	Composite reliability (CR)	CR > 0.9 (Not desirable)
			CR > 0.7-0.9 (satisfactory)
			CR > 0.6 for exploratory research
	Internal consistency	Cronbach's alpha (α)	α > 0.9 (Not desirable)
			α > 0.7-0.9 (satisfactory)
			α > 0.6 for exploratory research
2	Factor loadings/ Indicator reliability	Indicator loadings	Item loading ≥0.708 is recommended as the latent variables can explain at least 50 percent of its indicator's variance. Loadings of 0.4, 0.5, 0.6 and 0.7 can be accepted if it leads to Average Variance Extracted (AVE) that is larger than 0.5
3	Convergent validity	Average variance Extracted (AVE)	AVE > 0.50 suggests adequate convergent
4	Discriminant validity	Cross loading	Item's loading of each indicator is highest for its designated construct.
		Fornell Larcker	The square root of the AVE of a construct should be larger than the correlations between the construct and other constructs in the model
		Heterotrait-Monotrait (HTMT) ratio of correlation	i. HTMT Criterion • Values <0.85 (Kline, 2011) – Stringent, or, • <0.90 (Gold et al., 2001) – Conservative ii. $HTMT_{inference}$ (Henseler et al., 2015) • Perform bootstrapping; if upper nor lower limit does not contain a value of 1, discriminant validity is established.

Source: (Ramayah et al., 2018)

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Outer loadings are bivariate correlations between each item and their construct, representing each indicator's contribution to its assigned construct (Joseph F. Hair Jr. et al., 2022). If the outer loading value is less than 0.50, which is the cut-off value for a low indicator reliability (Joe F. Hair Jr. et al., 2020), the reflective indicator is deleted (Ramayah et al., 2018) and would subsequently improve CR and AVE. Finally, AVE measures the degree to which variance of the indicators explained the latent construct. To adequately achieve convergent validity, each latent construct should explain at least half of the assigned indicator's variance (Ramayah et al., 2018).

3.14.2 Internal consistency reliability

The second method, internal consistency reliability, has been predominantly measured using Cronbach's alpha. Nonetheless, composite reliability (CR) has emerged as an alternative measurement (Gefen et al., 2000). Similar to Cronbach's alpha, CR is the value of rho_c (ρ_c) which measures the internal consistency reliability i.e., a reliability test that determines whether the scores across items are similar. Conversely, CR does not require the assumption of equal indicator loadings like Cronbach's alpha (Joseph F. Hair Jr. et al., 2022). The accepted value for CR exploratory research such as this is values of more than 0.5 whereas values of between 0.7 and 0.9 is considered satisfactory. On the other hand, CR that is higher than 0.90 are considered unfavorable because it would mean all indicators measure the same phenomenon and doubtful to form a valid latent construct's reliability (Ramayah et al., 2018). This study will report both internal consistency reliability (Cronbach's alpha) and CR (rho_c or ρ_c).

3.14.3 Discriminant validity

Finally, the third method in the reflective measurement model assessment is discriminant validity. Discriminant validity determines the extent to which indicators of a construct is conceptually similar and yet sufficiently distinct from other constructs in the model when there is low correlation among these measures with other constructs (Joseph F. Hair Jr., Black, et al., 2019). Discriminant validity may be determined a number of ways including through cross loadings, Fornell-Larcker criterion (Fornell & Larcker, 1981) and the latest method introduced by Henseler et al. (2015), Heterotrait-Monotrait (HTMT) ratio of correlation. Henseler et al. (2015) and Franke & Sarstedt (2019) reviewed various methods of assessing discriminant validity using both criterion and statistical (inferential) test. Among the three, HTMT demonstrated higher specificity and sensitivity rates compared to cross loading and Fornell-Larcker criterions (Ramayah et al., 2018). Although HTMT criterion and $HTMT_{inference}$ detected discriminant validity issues reliably, Franke & Sarstedt (2019) concluded that inferential tests produce considerably less false positives over simple criterion cut-off values and should be preferred. Nevertheless, the study will report both HTMT criterion and $HTMT_{inference}$.

The first way of using HTMT as a criterion is by comparing it against a predetermined ratio, suggested by scholars at 0.85 and 0.90 (Gold et al., 2001; Kline, 2016). If the HTMT value is greater than the predetermined value, there is an issue of discriminant validity (Ramayah et al., 2018). The second way to use HTMT as a statistical test, i.e., $HTMT_{inference}$, is by performing bootstrapping technique at 90 percent confidence interval (CI). Discriminant validity is achieved when the result does not include the value of 1 (Ramayah et al., 2018).

3.15 Structural model assessment

Once an adequate measurement model validity has been assessed and established, the structural model can now be analyzed using PLS-SEM comprising five essential steps. Structural theory is a depiction of concepts among constructs with structural relationships. Based on the structural theory, a structural model (Table 3-18) is created representing how constructs would influence each other by using structural equations, and then the hypotheses are tested to assess the significance of these relationships (Joseph F. Hair Jr., Black, et al., 2019).

3.15.1 Collinearity

The first step in assessing a structural model is to ensure that the structural model has no collinearity issues (Ramayah et al., 2018). Discriminant validity checks for vertical collinearity issues but criterion-predictor (lateral) collinearity if left unchecked, could mask the strong causal effect in the study (Kock & Lynn, 2012). Hence, each predictor should have a VIF of lower than five (Kock, 2015) or preferably 3.3 (Kock & Lynn, 2012) to circumvent any collinearity issues.

3.15.2 Hypothesis Testing

Next, the significance and relevance of the structural model is assessed through a bootstrapping procedure, since PLS-SEM is a non-parametric test that does not assume data distribution normality (Ramayah et al., 2018). The bootstrap procedure begins with a large and pre-specified number of bootstrap samples with iterative random resampling from the original sample (with replacement) and estimates models for each of the subsamples. Bootstrap standard errors coefficients are then calculated to determine structural path significance. Larger subsamples are always better to improve

Table 3-18

Summary of Indices for Reflective Structural Model Analysis Using PLS-SEM

No.	Assessment	Name of index	Level of Acceptance/Source
1.	Lateral Collinearity	Variance Inflator Factor (VIF)	VIF ≤ 3.3 (Kock & Lynn, 2012) VIF ≤ 5.0 (Kock (2015)
2.	Path coefficient	Point estimate Interval estimate	p-value <0.10 t-value>1.28 values between CI LL 10 percent and UL 90 percent do not contain 0.
3.	R^2	coefficient of determination	0.26 – Substantial 0.13 – Moderate 0.02 – Weak (Cohen, 1988)
4.	f^2	Effect size to R^2	Direct relationships: 0.35 – large 0.15 – medium 0.02 – small <0.02 – none (Cohen, 1988)
5.	v^2 (Lachowicz et al., 2018)	Specific indirect effect size	Mediated relationship: 0.25 – large 0.09 – medium 0.01 – small 0.00 – none (Cohen, 1988)
6.	$Q^2_{predict}$ values	Root mean squared error of predictions (RMSE) or Mean absolute error (MAE)	Negative value of PLS-SEM RMSE/MAE minus Linear Model RMSE/MAE for: • none of the indicators, predictive relevance is not confirmed; • minority of indicators, low predictive power; • majority (>50 percent) of indicators, medium predictive power; and, • all indicators are negative, high predictive power. (Shmueli et al., 2019)

Source: Author's own compilation

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the precision of the estimated parameter distribution and, subsequently, the accuracy of inference testing (Becker et al., 2022) and hence, approximates normality of data (K. K.-K. Wong, 2019).

To run bootstrapping, the statistical parameters must be set. Most studies in the field of social science assumes a significance level (α) of 0.05, but since this study is an exploratory research, Hair et al. (2022) recommended a higher α of 0.10. In addition, given the fact that PLS-SEM may be applied to smaller sample sizes such as in this study, scholars recommended applying statistical significance of 0.10 (Joseph F. Hair Jr., Black, et al., 2019). The final parameter set is the one-tailed test, in view that the hypotheses are directional in nature. Subsequently, for this study, the statistical parameters for the bootstrapping are set as one-tailed, t-value of 1.28 at ten percent CI or α at 0.10, and run using 10,000 subsamples as recommended by Streukens and Leroi-Werelds (2016). Statistically, estimated path coefficients close to zero is indicative of weaker relationships, whereas values close to ±1 is indicative of strong positive or negative relationships (Joe F. Hair Jr. et al., 2020).

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The hypothesis testing for significance assessment will be based on the path coefficient (β); the point estimates t-value and p-value; as well as the interval estimates confidence interval bias lower (CI LL) and upper limits (CI LL) for hypothesis H_1-H_{13}. Whenever there are mixed results in a particular hypothesis, the interval estimates will prevail. The cut-off values to test hypothesis significance for point estimate is a p-value of equal or smaller than 0.100, a t-value greater than 1.28, whereas for an interval estimate, the values must not contain zero (Preacher & Hayes, 2004, 2008). Lastly, the

structural model's assessment is analyzed using coefficient of determination (R^2) score, the effect size (f^2) and $PLS_{predict}$ ($Q^2_{predict}$) (Joseph F. Hair Jr. et al., 2022).

3.15.3 Mediation analysis

A mediator describes how, or the mechanism by which, a certain effect would occur to the dependent variable (Ramayah et al., 2018). According to Baron & Kenny (1986), a mediator is a generative mechanism by which a focal independent variable influences the dependent variable. It is best considered in the case of a strong and meaningful relationship between the predictor and the criterion variable. As mentioned earlier, this PLS-SEM path modelling analysis will be executed with SmartPLS 4 version 4.0.9.6. software. The latest enhancements to a user-friendly and graphical nature of SmartPLS 4, the mediating effect of path models and predictive analysis is easily executed and reported for PLS-SEM analysis (Sabol et al., 2023).

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There are two types of approaches in theorizing mediation effect, namely, segmentation and transmittal (Rungtusanatham et al., 2014). In this study, the transmittal approach is applied, whereby the indirect effect between predictor and criterion variables are hypothesized. Granted, some researchers argue that fields of study such as psychology and social sciences could be explained by any number of possible causes; therefore it is inconsequential to establish a full or partial mediating effect in an empirical study (Hayes, 2013; Rucker et al., 2011; Rungtusanatham et al., 2014). Despite this, the latest PLS-SEM literature progression suggests that further examining the types of mediation to be beneficial (Joseph F. Hair Jr. et al., 2022; Nitzl et al., 2016).

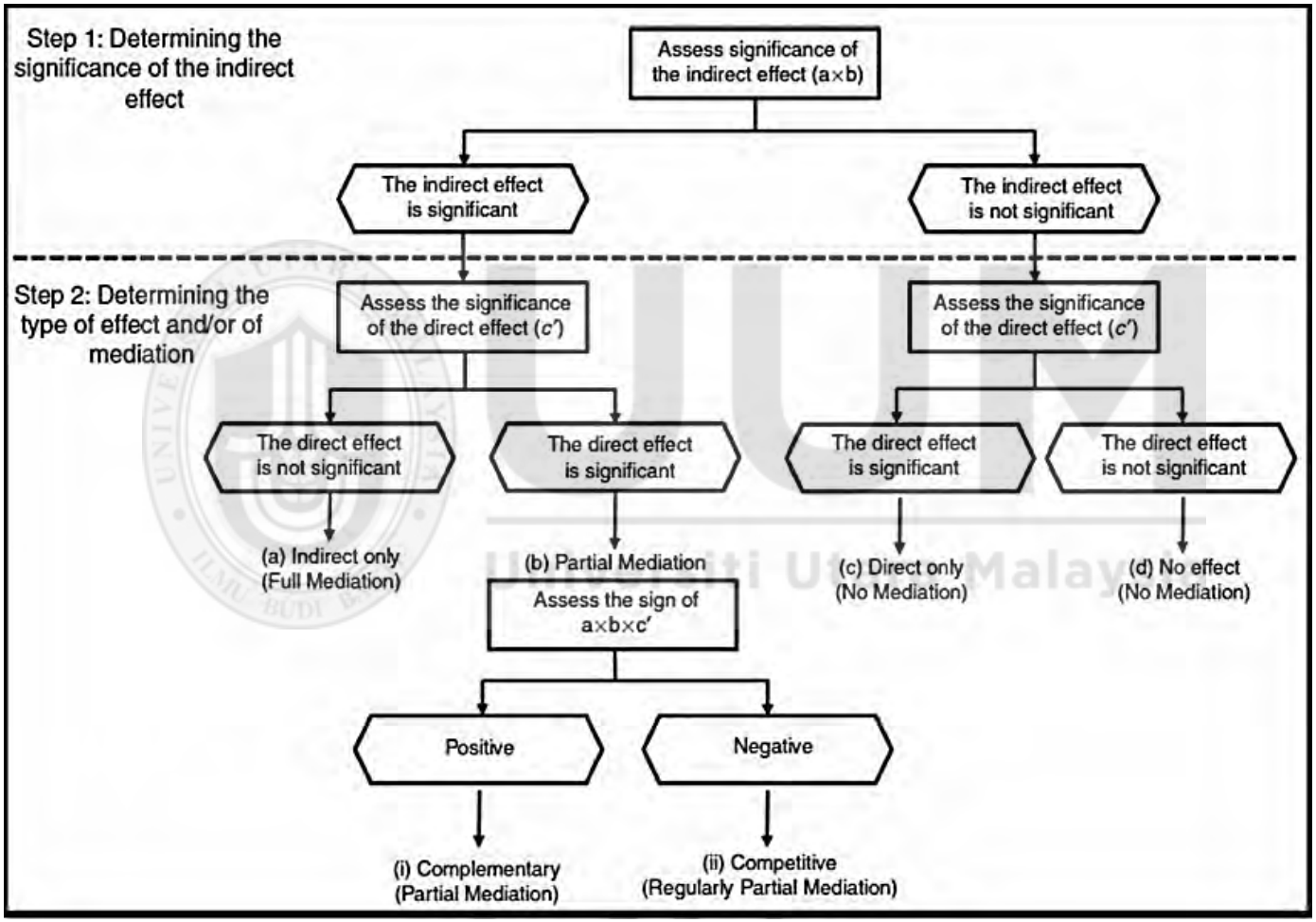


Figure 3-2
Advanced Mediator Analysis Procedure (Ramayah, 2018)

In their article, MacKinnon et al. (2007) and Nitzl et al. (2016) discussed the types of mediation to extend its analysis, which include full mediation, complementary partial mediation and competitive partial mediation. The consensus among scholars is that the indirect effect from predictor variable to criterion variable must first be significant, before advancing into classifying any partial mediation into complementary and competitive (Joseph F. Hair Jr. et al., 2021; Nitzl et al., 2016; Zhao et al., 2010). Figure 3-2 illustrates the complete procedure to determine the type of mediation effects for a hypothesis. A complementary partial mediation hypothesis or a "positive confounding" or "consistent model" (Zhao et al., 2010) means the intermediate variable positively influences the relationship between independent and dependent variables; whereas a competitive partial mediation will reduce the magnitude of the relationship (Ramayah et al., 2018).

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3.15.4 Coefficient of determination (R^2)

The level of R^2 determines the model's explanatory power (Joseph F. Hair Jr. et al., 2022) and represents the amount of variance in an endogenous construct explained by all linked exogenous constructs (Ramayah et al., 2018). The effect ranges between zero and one, with higher R^2 values indicating higher explanatory power. Generally, a higher R^2 value is preferable; nevertheless, 0.26, 0.13, and 0.02 indicates substantial, moderate, and weak predictive accuracy, respectively (Cohen, 1988). In fact, R^2 should also be interpreted against the context of the research, compared with other related studies or similar in model complexity (Joseph F. Hair Jr., Black, et al., 2019).

3.15.5 Effect size

Next, the criterion Cohen's effect size, f^2, is used to evaluate the change in R^2 when an exogenous construct is omitted from the model (Joseph F. Hair Jr., Black, et al., 2019). Cohen (1988) classified the values of f^2 of 0.35 as large, 0.15 as a medium, and 0.02 as small effect sizes of the exogenous latent variable; whereas f^2 value, which is less than 0.02, signifies no effect.

To calculate the indirect effect size for mediated relationships (v), square the individual β value for specific indirect effects (Lachowicz et al., 2018). For a model that contains interaction terms such as a mediator variable in this study (Becker et al., 2022; Memon et al., 2019), Cohen's effect size is still applied, albeit at lower effect size values. According to Lachowicz et al. (2018), a v^2 that is equal to zero is considered as no effect; v^2 that is equal to or greater than 0.01 is considered as a small effect; v^2 that is equal to or greater than 0.09 is considered as a medium effect; and finally, v^2 that is equal to or greater than 0.25 is considered as a large effect (Kenny, 2021).

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3.15.6 PLS-based predictive relevance

As for the final structural measurement criterion, two types of PLS-based predictive relevance can be utilized. The first one, Stone-Geisser's predictive relevance (Q^2) statistic (Geisser, 1974; Stone, 1974) is obtained through the blindfolding procedure. The second method, PLS-SEM $Q^2_{predict}$ ($PLS_{predict}$), will be applied in this study. Shmueli et al. (2016) developed $PLS_{predict}$ by using the training estimates from PLS-SEM to predict the test sample. The $PLS_{predict}$ method divides a sample into equal number of predetermined number of *k* subsets. Next, the k-1 subsets are combined to estimate the parameters, which would then be applied to predict the holdout sample.

This process is repeated until eventually, all the sample subsets would serve exactly once as the holdout sample (Sarstedt et al., 2022). In each cycle, the model estimates are then used to generate prediction statistics for the holdout samples. The $PLS_{predict}$ algorithm can be repeated *r* times to generate predictions based on the average of the different *r* estimated models. In this instance, to mimic PLS-SEM's single model for predicting a new observation, *r* is set to 1 (Joseph F. Hair Jr. et al., 2022).

The prediction statistics for $PLS_{predict}$ are calculated using root mean squared error (RMSE) or mean absolute error (MAE). RMSE is the preferred method of calculating prediction statistics. However, when the distribution of the prediction errors is highly non-symmetric, MAE is used instead. The resulting PLS-SEM RMSE or PLS-SEM MAE is then compared with the naïve mean value $Q^2_{predict}$ and the linear model (LM) (Shmueli et al., 2019). The $Q^2_{predict}$ value in generated by $PLS_{predict}$ compares the prediction errors of the PLS path model against simple mean predictions. This error term essentially refers to the difference between actual values and the predicted values of each indicator. If the $Q^2_{predict}$ values are equal to or less than zero, it is concluded that the predictive relevance is not confirmed. On the other hand, if $Q^2_{predict}$ values are more than zero, (i.e., positive), the PLS-SEM RMSE or PLS-SEM MAE is then benchmarked against either LM_RMSE or LM_MAE. Consequently, there will be four potential outcomes depending on the number of indicators that have PLS-SEM RMSE (or MAE) which are smaller than naïve LM benchmark, as follows:

i) if none of the indicators had lower PLS-SEM RMSE (or MAE) analysis in comparison to the naïve LM benchmark, it is concluded that the model has no predictive power;

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ii) if minority number of the indicators had lower PLS-SEM RMSE (or MAE) analysis in comparison to the naïve LM benchmark, it is concluded that the model has a low predictive power;

iii) if equal or majority number of indicators had lower PLS-SEM RMSE (or MAE) analysis in comparison to naïve LM benchmark, it is concluded that the model has a medium predictive power; or,

iv) if all the indicators had lower PLS-SEM RMSE (or MAE) analysis in comparison to naïve LM benchmark, it is concluded that the model has high predictive power.

3.16 Summary

This chapter discuss is the selection of research design and the steps carried out answers to the research questions. All items for measurement are variables and constructs were adopted from previous studies. This chapter also elaborates on population, sampling procedures, in explained the choice of the sampling frame which is the decision makers in Malaysian SMEs. Additionally, this chapter describes the data collection procedures and the statistical analysis methods, and the research framework validation exercise by experts in the field. The pretest study was conducted to ensure face validity of the measures, followed by a pilot study which was statistically in terms of reliability and validity, biases. Criteria for mediation analysis, measurement model and structural model assessments were discussed. The next chapter presents the results and discusses the analyses.

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CHAPTER FOUR
RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the empirical results of the data analyses undertaken for this study. It starts with the data preparation process prior to performing the data analysis using two different statistical analysis software packages, namely, Statistical Package for Social Sciences (SPSS) - version 28 and SMARTPLS 4. Initially, data screening to check for missing values, straight-lining of responses and multivariate outliers using SPSS, followed by a descriptive analysis about the SME profile and the measurement items. Next, SMARTPLS 4 was utilized to run partial least square – structural equation measurement (PLS-SEM) method for path modelling to test any survey bias, measurement model assessment and structural model assessment, particularly for hypothesis testing and evaluation of the mediation effect. Finally, the chapter summarizes the results of the hypothesis testing and model's predictive power before ending with a chapter summary.

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4.2 Data collection and Overview of results

The data collection exercise in the study was done using one channel, via online survey from the period of between end-February and end-August 2024. The sampling frame for the SMEs targeted were from two databases i.e. MPC and DOSM, totaling 15,270 small and medium enterprises after curated by removing wound up companies, missing email addresses, invalid email addresses, redundant company registration numbers between the two databases, as well as duplicate email addresses due to the companies being registered with SSM via company secretary firms. First, these two databases

were combined to eliminate any redundant email addresses/companies. Based on random sampling of every 7th company in the sampling frame, a total of 1,986 emails were sent with a cover letter explaining the purpose of the survey containing the instructions and link to the online questionnaire. Unfortunately, many emails bounced back, especially the ones from the DOSM database, for various reasons such as invalid domain name, email address, or the intended recipient has left the company. Many bounced emails were reviewed and upon further online search, it was found that many companies had gone out of business. Attempts were made to locate the most recent contact information via internet search to maximize the survey reaching sample respondents.

4.3 Response rate

Response rates from MPC and DOSM sampling frame were very low and slow, particularly since many of the SMEs in the databases were found to have been closed down especially since the 2020 COVID19 pandemic. To improve response rates, reminders were sent to the successfully sent but have yet to respond; the first reminder was after two weeks, the second reminder sent a month thereafter, and a final reminder sent two months thereafter. Eventually, after six months of follow-up, the survey yielded an effective response rate of 188/1,986 = 9.47 percent which is slightly higher than the average response rate for the two SME studies in Malaysia (Omar, 2018; Raja et al., 2016) at 8.67 percent.

4.4 Data screening

Questionnaires received were carefully examined through screening and data cleansing. The process ensures that the data is precise and adequate (Cooper and

Schindler, 2014). The data cleansing begins with downloading the responses tabulated from the online form, coding, and separating multiple response questions into multiple codes such as position in the company. Subsequently, the data undergoes a screening process whereby the researcher checks for missing data, responses were answered in a straight-lining method, and outlier analysis.

4.4.1 Missing value analysis

The study was administered fully via an online questionnaire, and the mandatory questions were controlled for responses before moving on to the next page. This has effectively prevented skipping questions and subsequently, there is no missing data.

4.4.2 Straight-lining pattern

During this stage of the screening, the researcher tested the response pattern to identify any respondents who straight-lined their responses by simply giving the same rating for all questions in the survey. SPSS software Version 28 was used to evaluate straight-lining patterns in this study by calculating the standard deviation for all variables and remove respondents with zero standard deviation. There were six cases detected with a straight-lining pattern for all questions in the independent variables/constructs, which were from ID cases 17, 68, 87, 89, 105, 147. All six cases were found to have answered 3's for all the items in the independent variables multi-item measurement and were removed from the sample datasets. A total of 182 respondents remained after the removal of the responses with a straight-lining pattern.

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4.4.3 Assessment of outliers

As mentioned earlier in the data screening section, SPSS Version 28 to run Mahalanobis Distance (D^2) to detect multivariate outliers. The degree of freedom was seven, as there are seven independent variables. No outliers were found based on the values D^2 equal to zero. Thus, it was concluded that outliers had no influence in this study (Appendix D).

4.5 Descriptive analysis

The descriptive analysis informed the frequency and percentage for the demographic profile of SMEs, cross tabulation of the 4IR technology adoption trends and their analysis. In addition, the descriptive analysis informed the mean and standard deviation of the independent, mediating, and dependent variables.

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4.5.1 Demographic profile of respondents

The demographic profile of the respondent SMEs is presented in Table 4-1, followed by cross tabulation of the adoption trends and their analysis. The summary shows that out of 182 datasets, the majority respondents to the survey were among the top management group, consisting of 113 SMEs or 62.1 percent.

Owner/CEO/Managing Director as well as 37 SMEs or 20.3 percent Senior Management/Head of Department. More than half (51.6 percent or 94 respondents) has worked for longer than 5 years, as evidenced by their senior management position in the company. In terms of strategy planning, almost 90 percent or 163 respondents have been involved. Also, almost half of the respondents possess a bachelor's degree as their highest qualification with 82 or 45.1 percent of respondents, whereas 53 or

Table 4-1
Demographic profile of respondents (n=182)

Demographic	Categories	Frequency	Percentage (%)
Position	Owner/CEO	113	62.1
	Senior Management/HoD	37	20.3
	Executive/Junior Management/etc.	32	17.6
Work Tenure	Less than 3 years	52	28.6
	3 – 5 years	36	19.8
	6 – 10 years	43	23.6
	11 – 15 years	30	16.5
	More than 15 years	21	11.5
Highest Education Level	School certificate	17	9.3
	Diploma/Professional	53	29.1
	Bachelor's degree	82	45.1
	Master's degree	25	13.7
	Doctorate degree	5	2.7
Gender	Male	130	71.4
	Female	52	28.6
Ownership	Sdn. Bhd.	119	65.4
	Limited Liability Partnership	5	2.7
	Partner	15	8.2
	Sole proprietorship	43	23.6
Years	Less than 3 years	29	15.9
Established	3 – 5 years	26	14.3
	6 – 10 years	37	20.3
	11 – 15 years	32	17.6
	More than 15 years	58	31.9

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Table 4-1
Demographic profile of respondents (n=182) (continued)

Demographic	Categories	Frequency	Percentage (%)
Locality	Urban	126	69.2
	Suburban	40	22.0
	Rural	16	8.8
Sector	Manufacturing	58	31.9
	Service	124	68.1
Firm Size	Small	157	86.3
	Medium	25	13.7
Strategy	Defender	33	18.1
Typology	Prospector	36	19.8
	Analyzer	82	45.1
	Reactor	31	17.0
Adopted 4IR	Yes	128	70.3
	No	54	29.7
Type(s) of 4IR	Cloud computing	75	58.6
technology	Other services, platforms, or infrastructure	83	64.8
	Internet of things (IoT)	70	54.7
Objective(s) of adoption	Sales, marketing and product/service development	76	59.4
	Production or service operations planning & quality control	75	58.6
	Functions specific to our industry	71	55.5
Total		**182**	**respondents**

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29.1 percent of respondents hold a diploma or a professional certificate. The final question about the demographic profile is concerning the gender of the respondents, and results show an overwhelming majority were male, comprising 163 or 89.6 percent of the respondents.

Subsequently, the descriptive analysis will relate to the profile of the SMEs. The biggest group of respondents were from SMEs established more than 15 years (n=58, 31.9 percent). Meanwhile, the smallest group of respondents were from SMEs that have been operating between 3 to 5 years (n=26, 14.3 percent). Altogether, almost half of the SME respondents were established more than 10 years ago (n=90, 49.5 percent). As for the type of ownership, majority of respondents were from SMEs registered as *Sendirian Berhad* (n=119, 65.4 percent), followed by sole proprietorship SMEs (n=43, 23.6 percent).

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In addition, urban SMEs constitute 126 or 69.2 percent of respondents, whereas 40 or 22 percent were from suburban and only 16 or 8.8 percent were from rural localities. Most respondent SMEs were from the service sector (n=124, 68.1 percent) compared to 58 or 31.9 percent of the manufacturing sector. Similarly, 157 or 86.3 percent were small-sized SMEs compared to only 25 or 13.7 percent medium-sized SMEs responded. With respect to the strategy typology, 82 or 45.1 percent Analyzer were represented in the survey, followed by similar percentages of Prospector, Defender and Reactor at 36 (19.8 percent), 33 (18.1 percent) and 31 (17 percent) SMEs, respectively.

Adopters make up 128 SMEs or 70.3 percent versus 54 or 29.7 percent non-adopters. Respondents were allowed to choose all applicable functions and the types of technologies adopted. The study found that the top three types of 4IR technologies the

SMEs reported adopting are cloud computing; Other services, platforms, or infrastructures (such as e-commerce or e-payment gateway); as well as IoT. The top three functions adopted were: Sales, marketing and product/service development; Production or service operations planning & quality control; and lastly, Functions specific to our industry. More than 70 SMEs reported the adoption of each type of 4IR technology and function in these top three categories.

4.5.2 Crosstabs

This section presents the cross tabulation between selected demographic profile and the adoption trends, as well as their analyses.

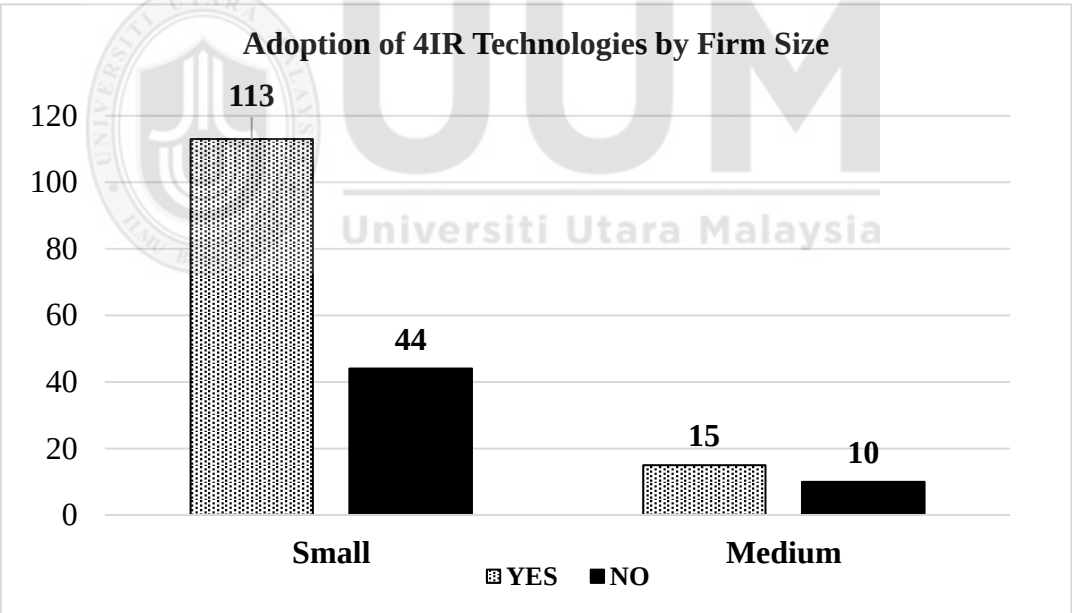


Figure 4-1
Adoption of 4IR Technologies by Firm Size

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Data was collected from 182 SMEs comprising 157 small- and 25 medium-sized companies. The descriptive statistics show that 113 out 157, or almost 72 percent of the small-sized SMEs have adopted 4IR technologies, whereas 15 out of 25, or 60 percent of the medium-sized SMEs have done so (Figure 4-1). Overall, 70.3 percent of the SME respondents have adopted 4IR technologies.

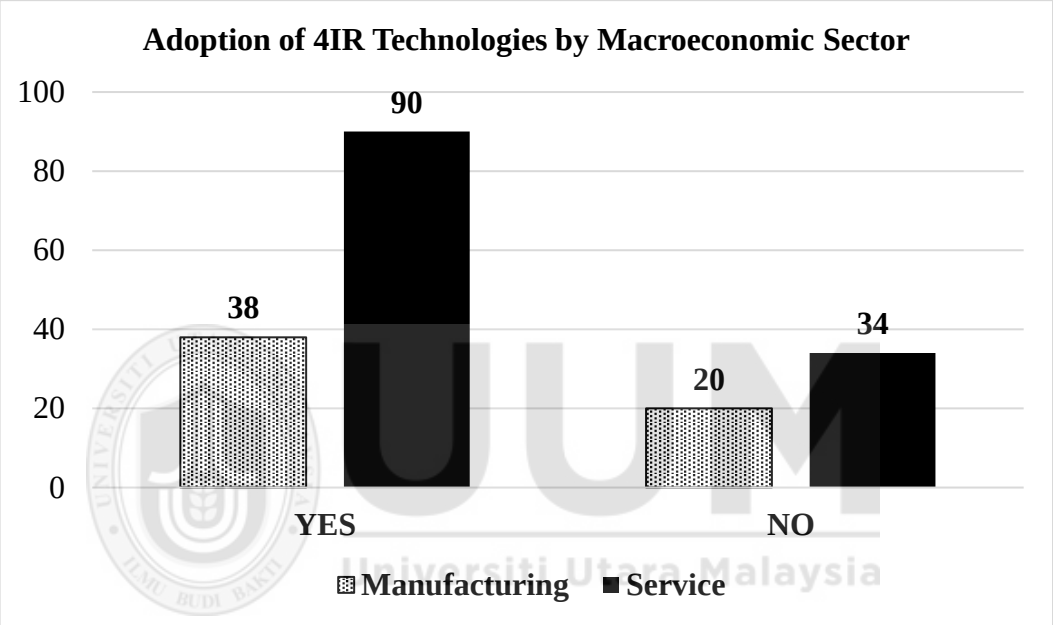


Figure 4-2
Adoption of 4IR Technologies by Macroeconomic Sector

As for the macroeconomic sector category, 58 respondents were from manufacturing whereas 124 respondents were from the service sector (Figure 4-2). Overall, 70.3 percent have adopted 4IR technologies, comprising 38 and 90 SMEs from manufacturing and service sectors, respectively. Within the manufacturing sector, 65.5 percent have adopted 4IR technologies compared to 72.6 percent within the service sector.

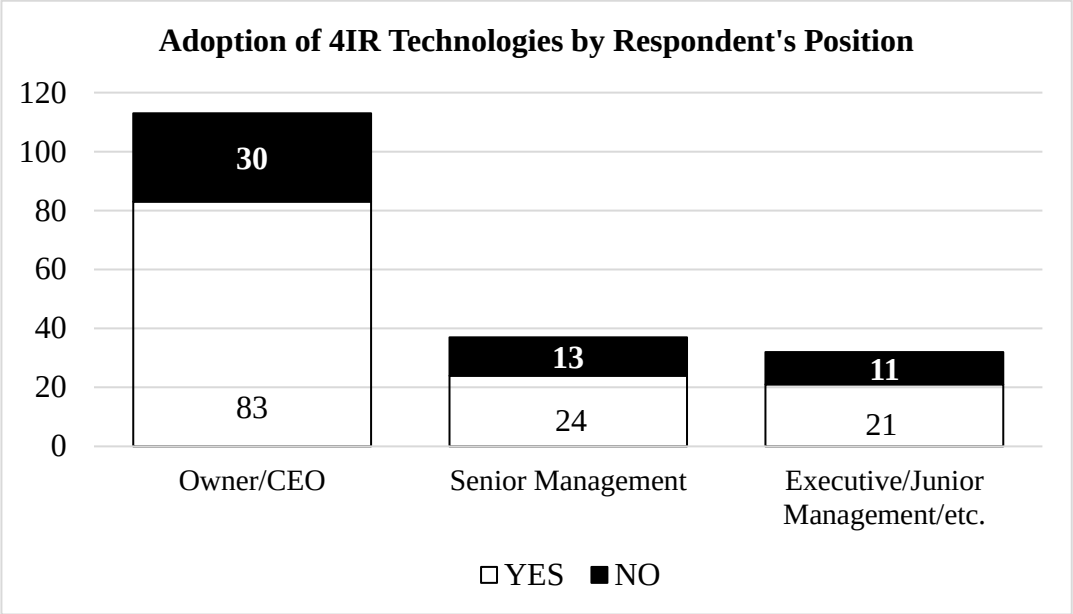


Figure 4-3
Adoption of 4IR Technologies by Respondent's Position

In terms of the respondent's position (as per Figure 4-3), a total of 128 adopters, i.e., 83 out of 113 Owner/CEO (73.5 percent), and 24 out of 37 Senior Management (64.9 percent) indicated their companies have already adopted 4IR technologies. Overall, these two categories of top management make up 107 or 83.6 percent of the vast majority of the 128 SMEs that have adopted 4IR technologies.

Among the 182 respondent SMEs, strategy typology Analyzer was the majority adopters with 61 or 33.5 percent, followed by Prospector and Reactor with 24 each or 13.2 percent, and Defender with 19 or 10.4 percent adopters (Figure 4-4). Within the respective strategy typology, Reactor led with 77.4 percent adopters out of 31 SMEs, followed by Analyzer with 74.4 percent out of 82 SMEs, Prospector with 66.7 percent out of 36 SMEs, and defender with 57.6 percent out of 33 SMEs.

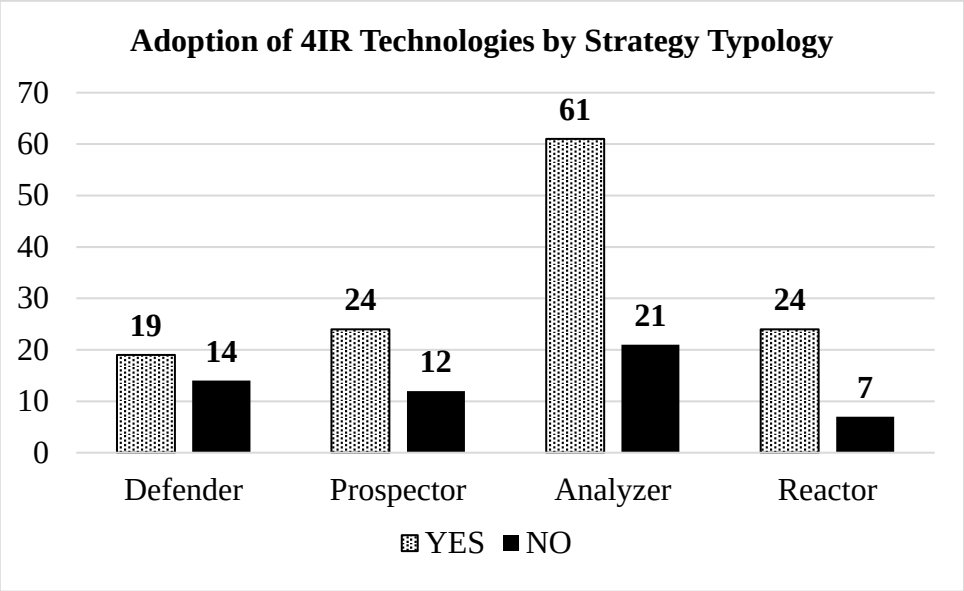


Figure 4-4
Adoption of Technologies by Strategy Typology

With respect to locality (Figure 4-5), a total 89 out of 126 adopters were urban SMEs (70.6 percent), 28 out of 40 were suburban SMEs (70 percent), and lastly, 11 out of 16 rural SMEs (68.8 percent) have adopted 4IR technologies. The study also found that within the 128 total adopters, 89 or 69.5 percent were urban SMEs, 28 or 21.9 percent were suburban SMEs and only 11 or 8.6 percent were rural SMEs. In conclusion, the overwhelming majority of adopters were from urban locality.

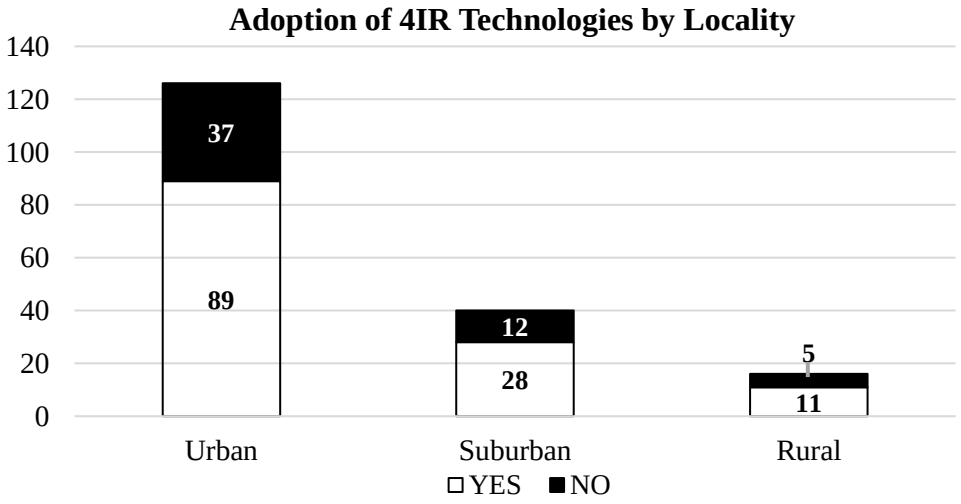


Figure 4-5
Adoption of 4IR Technologies by Locality

Finally, in terms of years of establishment (Figure 4-6), the highest number of adopters were in SMEs which are older than 15 years, whereas the other four categories recorded about the same number of adopters of between 21 and 24 SMEs each. Within each category, SMEs established for 3 to 5 years (n=26) had the highest percentage of adopters at 84.6 percent or 22 SMEs; followed by SMEs established between 10 to 15 years (n=32) at 75 percent or 24 SMEs; and SMEs established for less than 3 years (n=29) at 72.4 percent or 21 SMEs; SMEs established for more than 15 years (n=58) at 65.5 percent or 38 companies; and SMEs established between 5 to 10 years (n=37) at 62.2 percent or 23 companies.

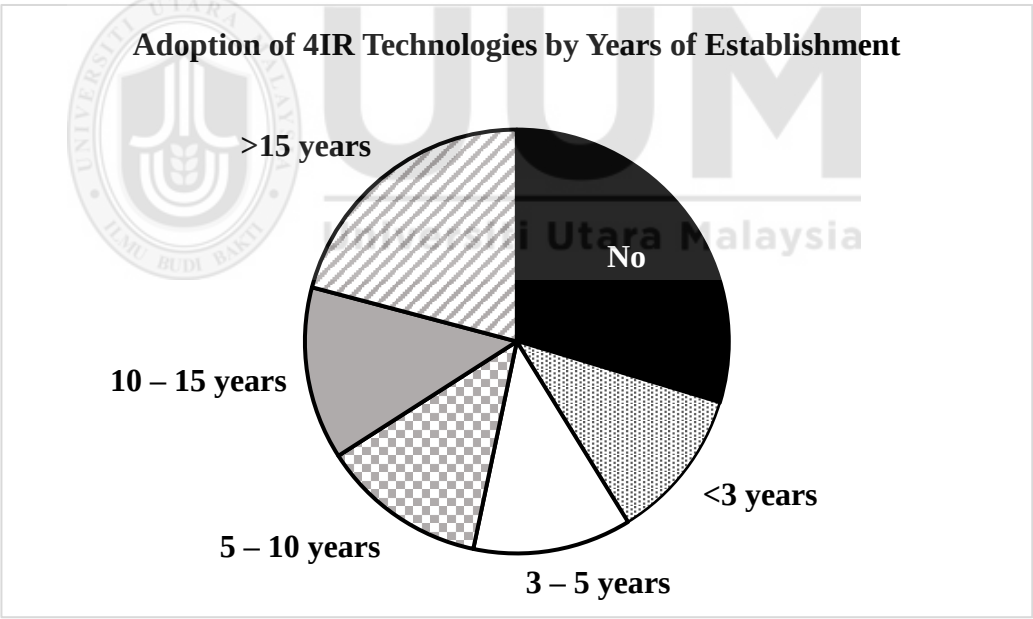


Figure 4-6
Adoption of 4IR Technologies by Years of Establishment

4.5.3 Descriptive analysis of constructs

Table 4-2 tabulates the mean and standard deviation of the independent, mediating, and dependent variables.

Table 4-2
Descriptive statistics of constructs

Constructs	N	Mean	Standard Deviation	Variance
Relative Advantage (RA)	182	3.99	0.70	0.49
Complexity (CPLX)	182	3.31	0.84	0.71
Cost (COST)	182	3.67	0.76	0.57
Top Management Support (TMS)	182	3.64	0.75	0.57
Firm Size (SIZE)	182	3.06	0.78	0.60
Competitive Pressure (COMP)	182	3.29	0.71	0.50
Government Support (GOVT)	182	3.28	0.93	0.87
4IR Adoption (ADOPT)	182	2.89	1.31	1.72

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Overall, all the constructs recorded a mean of less than four on a scale of one (strongly disagree) to five (strongly agree), and three is neutral. Relative advantage scored the highest mean of 3.99, whereas the lowest mean was recorded by the dependent variable, 4IR Adoption, which was lower than the three, at 2.89. This means that among adopters, the number of technologies adopted are less than four types (out of seven), whereas the frequency of usage levels is less than "quite often" and total time spent on average is "less than 4 hours daily".

4.6 Normality test

In the structural model assessment, the multivariate skewness and kurtosis is tested as recommended by Hair et al. (2022) and Cain et al. (2017). The results in Figure 4-7 shows that the collected data was not multivariate normal because Mardia's multivariate skewness ($\beta = 7.483$, $p < 0.01$) and Mardia's multivariate kurtosis

(β=86.441, p< 0.01) were both above the thresholds of equal to less than 3 and 20, respectively. Thus, based on Becker et al. (2023), the path coefficients, the standard errors, t-values and p-values for the structural model using a 10,000-sample re-sample bootstrapping procedure are reported (Ramayah et al. 2018).

Output of skewness and kurtosis calculation

```
Sample size:  182
Number of variables:  8

Univariate skewness and kurtosis
                   Skewness SE_skew Z_skew Kurtosis SE_kurt Z_kurt
ADOPT                -0.593    0.18 -3.294   -0.858   0.358 -2.394
CMPLX                -0.049    0.18 -0.269   -0.118   0.358 -0.330
COMP                  0.120    0.18  0.665    0.070   0.358  0.196
COST                 -0.271    0.18 -1.506    0.328   0.358  0.915
GOV                  -0.290    0.18 -1.610   -0.004   0.358 -0.011
Relative.Advantage   -0.263    0.18 -1.462   -0.306   0.358 -0.854
SIZE                  0.028    0.18  0.157    0.505   0.358  1.409
TMS                  -0.280    0.18 -1.555    0.682   0.358  1.904

Mardia's multivariate skewness and kurtosis
                b         z     p-value
Skewness  7.483219 226.990972 1.324004e-08
Kurtosis 86.441734   3.435172 5.921774e-04
```

Figure 4-7
Multivariate skewness and kurtosis

4.7 Full collinearity test

Since the data was collected using a single source, we first tested the issue of common method bias (CMB) by following the suggestions of Kock and Lynn (2012), and Kock (2015) to test using the full collinearity method. In this method all the variables in the research framework will be regressed against a common variable and if the VIF equal to or less than 3.3 (Kock & Lynn, 2012) or less than five , then there is no bias from

the single source data. The full collinearity analysis (Table 4-3) yielded all VIF values of less than 3.3, consequently, it can be concluded that single source bias is not a serious issue with the data.

Table 4-3
Single source bias assessed via full collinearity test

Variable	VIF
4IR Adoption Level (ADOPT)	1.498
Complexity (CMPLX)	1.681
Competitive Pressure (COMP)	1.682
Cost (COST)	1.597
Government Support (GOVT)	1.333
Relative Advantage (RA)	1.467
Firm Size (SIZE)	1.682
Top Management Support (TMS)	1.887

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4.8 Measurement model assessment

The measurement model (Figure 4-8) was assessed to determine its construct reliability and validity using convergent validity, internal consistency, and discriminant validity using a two-step approach as recommended by Anderson and Gerbing (1988). The measurement model's validity and reliability of the instruments was done using the guidelines of Hair et al. (2022) and Ramayah et al. (2018), followed by the structural model, to test the hypotheses developed.

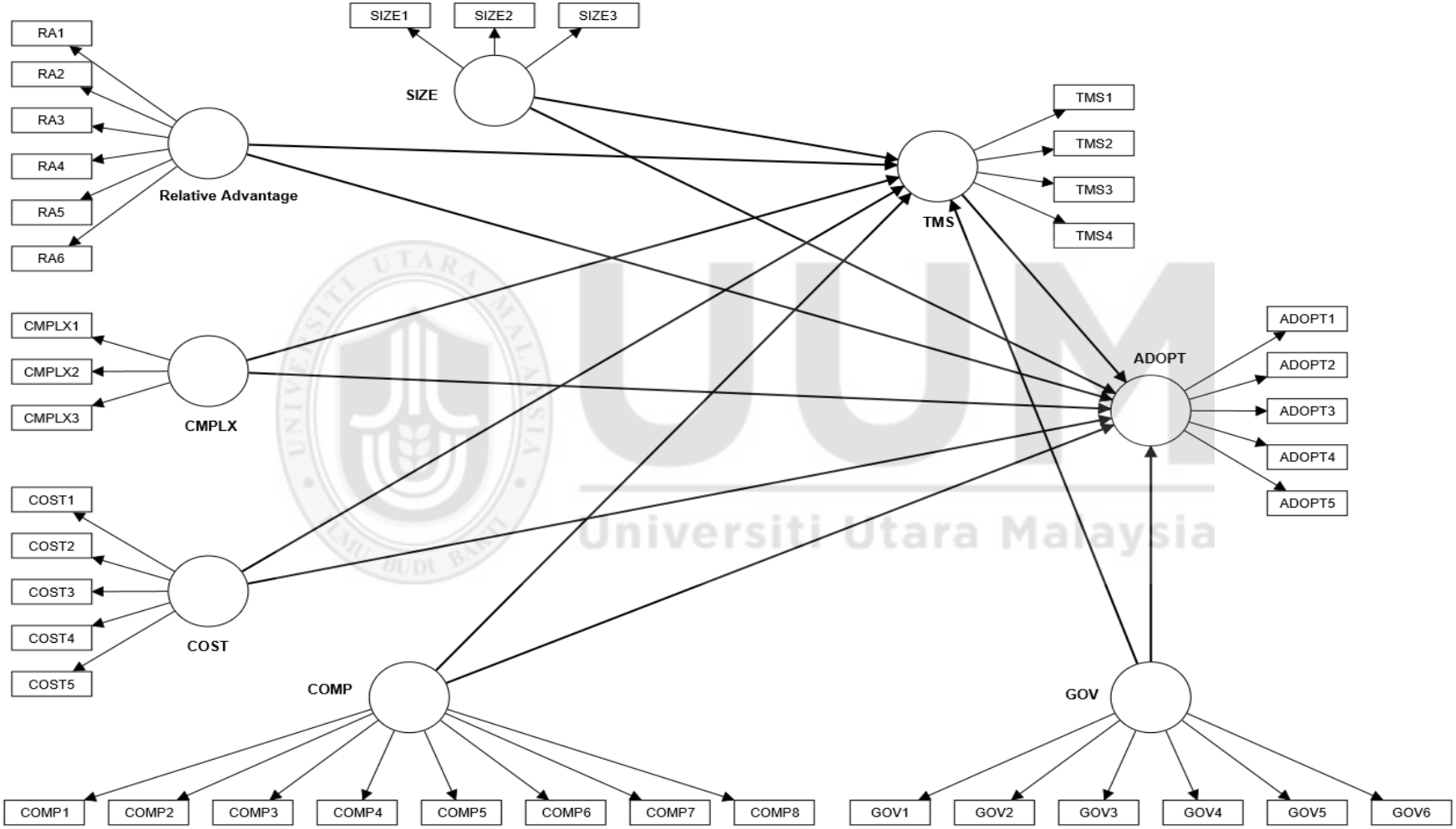


Figure 4-8
Measurement Model

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4.8.1 Convergent validity

First, the convergent validity was assessed, whereby any items with outer loadings below 0.50 would be deleted. In this model, the loading values ranged for all factors were between 0.582 and 0.946 (Table 4-4). Thus, no items were deleted as all the loadings were higher than the 0.50 threshold. Next, the AVE values were examined for all constructs to verify if the values were all above 0.50. It was found that all constructs have an AVE value of more than the threshold, and thus, the model retains all of its seven constructs. Details of measurement model values are in Appendix E.

4.8.2 Internal consistency reliability

Secondly, overall CR was assessed and found satisfactory, exceeding the threshold of 0.7 for both rho_c (ρ_c) and Cronbach's alpha (Table 4-4). Thus, in this study, it can be concluded that CR criteria were all met. This completes the measurement model assessment for this study and all criteria verified have met the requirements.

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Table 4-4
Construct reliability and validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average variance extracted (AVE)
4IR_ADOPT	0.916	0.926	0.938	0.754
COMPLX	0.877	0.909	0.924	0.803
COMP	0.895	0.927	0.916	0.582
COST	0.882	0.929	0.896	0.633
GOVT	0.952	0.958	0.961	0.805
RA	0.927	0.933	0.942	0.732
SIZE	0.696	0.715	0.821	0.605
TMS	0.932	0.932	0.952	0.831

4.8.3 Discriminant validity

The second step to the measurement model assessment is to examine the discriminant validity using HTMT criterion and $HTMT_{inference}$ (Franke & Sarstedt, 2019; Henseler et al., 2015). HTMT criteria should be equal to or less than 0.85 or 0.90. As presented in Table 4-5, the values of HTMT were all lower than 0.85. Hence, it is shown that the respondents understood that all seven constructs are distinct. As recommended by Franke & Sarstedt (2019), HTMT bootstrapping was also conducted to assess discriminant validity (Table 4-6). The results were acceptable because the upper limits of the CI were not greater than 1. Collectively, these tests proved that the measurement items are both valid and reliable.

Table 4-5
Discriminant validity using HTMT criterion

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1. 4IR_ADOPT								
2. COMPLX	0.133							
3. COMP_ENV	0.327	0.299						
4. COST	0.075	0.715	0.327					
5. GOVT	0.287	0.164	0.433	0.214				
6. RA	0.410	0.072	0.361	0.140	0.370			
7. SIZE	0.383	0.367	0.668	0.289	0.385	0.320		
8. TMS	0.558	0.042	0.432	0.122	0.364	0.546	0.545	

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Table 4-6
Discriminant Validity using HTMT$_{inference}$

	Original sample (O)	**Sample mean (M)**	**10%**	**90%**
CMPLX - ADOPT	0.133	0.149	0.082	0.230
COMP - ADOPT	0.327	0.330	0.242	0.415
COMP - CMPLX	0.299	0.310	0.208	0.415
COST - ADOPT	0.075	0.117	0.074	0.174
COST - CMPLX	0.715	0.715	0.646	0.782
COST - COMP	0.327	0.334	0.220	0.449
GOVT - ADOPT	0.287	0.286	0.197	0.375
GOVT - CMPLX	0.164	0.177	0.095	0.270
GOVT - COMP	0.433	0.440	0.344	0.534
GOVT - COST	0.214	0.221	0.113	0.334
RA- ADOPT	0.410	0.409	0.318	0.498
RA- CMPLX	0.072	0.114	0.074	0.162
RA- COMP	0.361	0.365	0.279	0.450
RA- COST	0.140	0.168	0.096	0.260
RA- GOVT	0.370	0.367	0.275	0.457
SIZE - ADOPT	0.383	0.385	0.298	0.469
SIZE - CMPLX	0.367	0.377	0.249	0.499
SIZE - COMP	0.668	0.668	0.572	0.760
SIZE - COST	0.289	0.309	0.199	0.426
SIZE - GOVT	0.385	0.385	0.275	0.492
SIZE - RA	0.320	0.332	0.242	0.425
TMS - ADOPT	0.558	0.559	0.489	0.626
TMS - CMPLX	0.042	0.104	0.054	0.174
TMS - COMP	0.432	0.433	0.329	0.536
TMS - COST	0.122	0.159	0.094	0.244
TMS - GOVT	0.364	0.363	0.249	0.472
TMS - RA	0.546	0.546	0.467	0.622
TMS - SIZE	0.545	0.543	0.439	0.642

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4.9 Structural model assessment

The study empirically assessed two structural models, i.e., the full relationship between the predictor variables (IVs) and the criterion variable (DV), and then the full, direct and indirect effects that the mediator variable has on IV and DV (Appendix F). As discussed in Chapter 3, there are four steps in the structural model assessments which includes hypothesis testing to assess the significance and relevance of the structural relationships, the explanatory power using coefficient of determination (R^2) score, the magnitude of an IV's effect size (f^2) has on DV; and finally, the predictive power using $PLS_{predict}$ ($Q^2_{predict}$).

4.9.1 Collinearity

As recommended by Hair et al. (2022), the normality and collinearity of data collected was tested under section 3.13 Testing of survey bias. There were found to be no collinearity issues (Table 4-3) with all of VIF values are less than 3.3. However, since the test of survey bias proved that the data distribution is not multivariate normal, a bootstrapping procedure was employed at 0.10 significance level or 90 percent CI, a one-tailed test, with 10,000 sub samples. Figure 4-9 illustrates the graphical path diagram of the bootstrapping procedure (Ringle et al., 2024).

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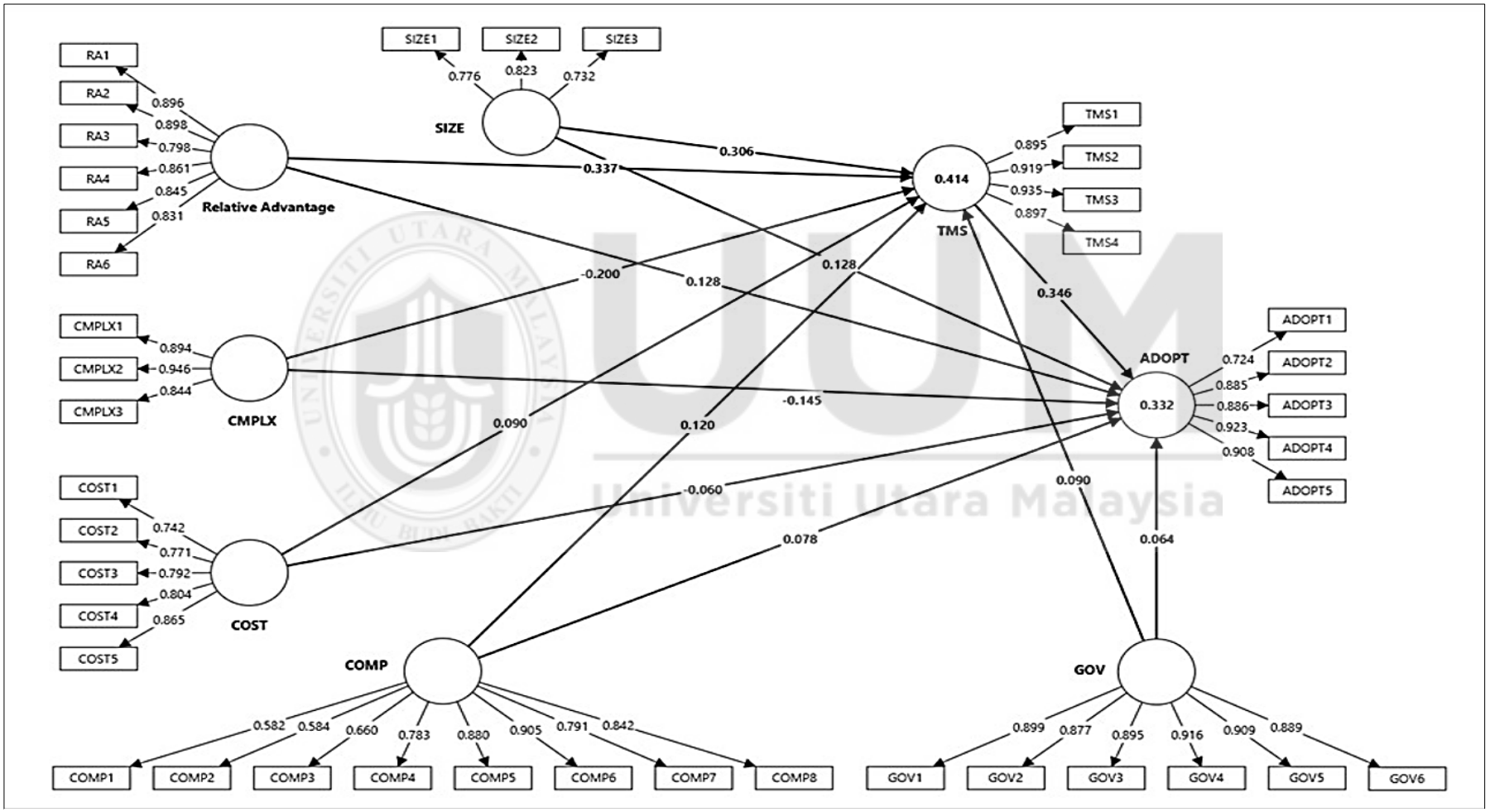


Figure 4-9
Graphical path diagram of the structural model

First, in evaluating the structural model, the hypothesis testing is conducted and tabulated (Table 4-7, Table 4-8, Table 4-9). The tables contain the path coefficient (β); the point estimates t-value and p-value; as well as the interval estimates confidence interval bias lower (CI LL) and upper limits (CI LL) for hypothesis H_1-H_{13} which will guide the decision on whether the relationships are significant and supported. Whenever there are mixed results for a particular hypothesis, the interval estimates will prevail. As per section 3.15.2 Hypothesis Testing, the thresholds for point testing significance is a p-value of equal or smaller than 0.100, a t-value greater than 1.28 and an interval estimate that does not contain zero. As for the mediation analysis to identify the types of mediation effect for each hypothesis H_8-H_{13}, whether it is no mediation effect, full mediation or partial (complementary or competitive) mediation. Complementary partial mediated effect happens when the indirect effect and direct effect are both significant, and their β product multiplication is positive. On the other hand, competitive partial mediation happens when the indirect effect and direct effect are both significant, but their β product multiplication is negative. Finally, no mediation effect is when both indirect and direct effects are not significant.

4.9.2 Hypothesis testing – Total effects

In evaluating the structural model, the total, direct and indirect effects of the hypotheses were evaluated with the bootstrapping results. Table 4-7 tabulates the results of the total effects from H_1-H_7 hypothesis testing. Based on the interval estimates, all the hypotheses except H_3 are found to be significant and supported the hypotheses between individual TOE factors and 4IR technology adoption (ADOPT) among SMEs. The individual hypothesis results are discussed as follows:

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H_1: There is a positive relationship between relative advantage and the adoption of 4IR technologies among SMEs.

The first hypothesis, H_1, means that a company tend to adopt 4IR technologies if it leads to more advantages than not. Based on the evaluation of the total effect between relative advantage (RA) as per Table 4-7, RA is significant and positively related to ADOPT with point estimate values of $\beta = 0.245$, $t = 3.676$, and $p = 0.000$ at $\alpha = 0.10$. Moreover, between the BCI LL 10% of 0.155 and the UL 90% of 0.327, the interval estimate result for H_1 does not contain zero. In conclusion, both the point and interval estimate results found that there is a significant and positive relationship between RA and ADOPT, and thus, the finding supports H_1. The result of this study is consistent with other researchers (Maroufkhani, Tseng, et al., 2020; Mohd Isa & Alenezi, 2022; Yaseen et al., 2021) who found that in the context of 4IR technology adoption, SMEs obtain advantages in terms of economic profitability in the form of cost savings, higher productivity, and better margin, resulting in higher profitability. Besides, there are also technological benefits enjoyed by the adopters in improving lengthy workflows and complicated business processes, shortening the supply value chain, and even increasing employee satisfaction by allowing flexibility to work from home. Furthermore, the relative advantage offered by 4IR technologies also extends to opening up new business opportunities and scaling up without traditionally more investments. Case in point is the startups that were able to grow into unicorn companies in a much shorter period compared to large non-technology companies.

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Table 4-7

Hypothesis testing total effects

Hypothesis	Relationship	Std Beta (β)	t-value	p-value	BCI LL 10%	BCI UL 90%	f^2	Decision	
H_1	RA → ADOPT	0.245	3.676	0.000	0.155	0.327	0.02	significant	supported
H_2	CPLX → ADOPT	-0.215	2.634	0.004	-0.325	-0.124	0.02	significant	supported
H_3	COST → ADOPT	-0.029	0.291	0.386	-0.140	0.121	0.00	not significant	-
H_4	SIZE → ADOPT	0.233	3.101	0.001	0.140	0.332	0.02	significant	supported
H_5	TMS → ADOPT	0.346	4.241	0.000	0.241	0.449	0.11	significant	supported
H_6	COMP → ADOPT	0.120	1.477	0.070	0.013	0.219	0.01	significant	supported
H_7	GOVT → ADOPT	0.095	1.438	0.075	0.011	0.180	0.01	significant	supported

Note: significance level of $\alpha = 0.10$ or 90% confidence interval with a bootstrapping of 10,000

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H_2: There is a negative relationship between complexity and the adoption of 4IR technologies among SMEs

Even to established large corporations, 4IR technologies are admittedly extremely complicated in nature and involve interconnectivity between cyber-physical systems. It is therefore expected for SMEs to find it difficult to navigate the adoption of these technologies, notwithstanding the competitive advantages to be gained. As a result, the hypothesis, H_2, postulated that the higher the complexity of the 4IR technologies, the lower the adoption. Based on the evaluation of the total effect between complexity (CPLX) as per Table 4-7, CPLX is significant and negatively related to ADOPT with point estimate values of $\beta = -0.215$, $t = 2.634$, and $p = 0.004$ at $\alpha = 0.10$. Moreover, between BCI LL 10% of -0.325 and UL 90% of -0.124, the interval estimate result for H_2 does not contain zero. Hence, both the point and interval estimate results found that there is a significant yet expected negative relationship between CPLX and ADOPT, and thus, the finding supports H_2. This is in agreement with prior empirical studies (Khayer et al., 2021; A. Lutfi et al., 2022; Pathan et al., 2017; Skafi et al., 2020; H. Wang et al., 2016).

A successful integration of 4IR technologies can significantly impact the growth and development of SMEs. To achieve this, SMEs must carefully adopt 4IR technologies that match the appropriate level of complexity for their company. Although it has been just over a decade in the 4IR era, the unprecedented speed of advancements in 4IR technologies, particularly with 5G capabilities, have provided SMEs with the opportunity to leverage technologies. Service sector SMEs can initially adopt Software as a Service (SaaS), e-commerce, and social media platforms, to propel their growth. Manufacturing sector SMEs, on the other hand, could adopt 4IR technologies such as

sensors to monitor quality in production lines and diversify into servicification of their product offerings. In these instances, SMEs may discover that the level of complexity involved to be more manageable, while simultaneously reaping the benefits of the adopted technologies.

H_3: There is a negative relationship between cost and the adoption of 4IR technologies among SMEs

The hypothesis H_3 posited that cost has a negative relationship with 4IR technology adoption. By and large, SMEs are genuinely facing financial constraints in the ever-escalating costs of doing business. Hence, cost has always been considered a barrier to technology adoption by SMEs, despite the upside of its potential returns to the company. Based on the evaluation of the total effect between cost (COST) as per Table 4-7, H_3 is not significant and thus, there is no relationship between COST and ADOPT with point estimate values of $\beta = -0.029$, $t = 0.291$, and $p = 0.386$ at $\alpha = 0.10$. Moreover, between BCI LL 10% of -0.140 and UL 90% of 0.121, the interval estimate result for H_3 contains zero. Since both the point and interval estimate results found H_3 to be not significant, thus, there is no relationship between COST and ADOPT among SMEs. This is contrary to preceding studies (Ngah et al., 2022; Raut et al., 2017; Verma & Bhattacharyya, 2017) which found that the higher the cost, the lower the technology adoption. Instead, this study rejected the hypothesis H_3 and proved that cost is not a deterrent to 4IR technology adoption among SMEs. One possible explanation could be due to cost in Malaysia is heavily supplemented by the government through the various incentives provided to boost 4IR adoption among SMEs. Another reason cost is not a significant factor could be explained by the declining cost of adoption due to these technologies reaching economies of scale and the network effect at this stage of

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the 4IR. It was highlighted earlier that 4IR technologies are advancing at unprecedented speed, such that after only a decade in the era, these technologies have become more affordable. For instance, with AI services, cloud computing, e-commerce platforms, SMEs have access to technologies that are lower in costs.

H_4: There is a positive relationship between firm size and the adoption of 4IR technologies among SMEs

In the TOE framework, firm size is a factor of adoption. The study postulates H_4 in that the bigger the firm's size, the better the 4IR technology adoption. Prior studies have also shown that the larger SME companies would have more resources compared to smaller SMEs (AL-Shboul, 2019; Pathan et al., 2017; Yaseen et al., 2021; Zakari Usman et al., 2019). Besides, by adopting 4IR technologies, even smaller companies could potentially disrupt the industry's competitive landscape. Based on the evaluation of the total effect between firm size (SIZE) as per Table 4-7, SIZE is significant and positively related to ADOPT with point estimate values of $\beta = 0.233$, $t = 3.101$, and $p = 0.001$ at $\alpha = 0.10$. Moreover, between the BCI LL 10% of 0.140 and the UL 90% of 0.332, the interval estimate result for H_4 does not contain zero. In conclusion, both the point and interval estimate results found that there is a significant and positive relationship between SIZE and ADOPT, and thus, the finding supports H_4. The study's finding supported the hypothesis in that firm size plays a role in influencing 4IR technology adoption among SMEs in Malaysia. Harnessing 4IR adoption will further boost profitability as well as productivity of the company, and ultimately, growth of the company.

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H_5: There is a positive relationship between top management support and the adoption of 4IR technologies among SMEs

Top management plays a crucial role in technology adoption as their support would determine the strategic direction and specific actionable plans for the company. An SLR conducted by Aldossari et al. (2023) resulted in top management support being ranked as the third highest factor in literature and ranked first by experts among 42 influencers of BDA adoption. Hence, this study hypothesizes a positive relationship between top management support (TMS) and 4IR technology adoption. Based on the evaluation of the total effect between TMS as per Table 4-7, TMS is significant and positively related to ADOPT with point estimate values of $\beta = 0.346$, $t = 4.241$, and $p = 0.000$ at $\alpha = 0.10$. Moreover, between the BCI LL 10% of 0.241 and the UL 90% of 0.449, the interval estimate result for H_5 does not contain zero.

In conclusion, both the point and interval estimate results found that there is a significant and positive relationship between TMS and ADOPT, and thus, the finding supports H_5. The significance of this result proved that top management support is a major determinant factor that would drive higher 4IR technology adoption. Therefore, it is imperative for top management to create a conducive environment as well as allocate appropriate resources towards supporting the adoption of 4IR technologies in their companies. In turn, these companies would be able to realize economic profitability and gain competitive advantage.

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H_6: There is a positive relationship between competitive pressure and the adoption of 4IR technologies among SMEs

Competitive pressure is a factor in the environmental context that influences the decision for SMEs to adopt 4IR technologies. The more intense the competitive pressure, the more likely the 4IR adoption will happen, in order not to lose competitive advantage. Moreover, SMEs that are suppliers to larger companies could potentially become obsolete and lose markets to their competitors if they choose not to adopt the 4IR technologies. Based on the evaluation of the total effect between competitive pressure (COMP) as per Table 4-7, COMP is significant and positively related to ADOPT with point estimate values of $\beta = 0.120$, $t = 1.477$, and $p = 0.070$ at $\alpha = 0.10$. Moreover, between the BCI LL 10% of 0.013 and the UL 90% of 0.219, the interval estimate result for H_6 does not contain zero. In conclusion, both the point and interval estimate results found that there is a significant and positive relationship between COMP and ADOPT, and thus, H_6 is supported. This means that the pressure to adopt could come from the presence of adopter competitors, the threat of substitutes available to customers, and suppliers' bargaining power. As a result, SMEs that face competitive pressure will be compelled to adopt 4IR technologies or risk losing out on opportunities.

H_7: There is a positive relationship between government support and the adoption of 4IR technologies among SMEs

Lastly, the study hypothesizes H_7 which postulated that government support positively influences the technology adoption among SMEs in Malaysia. It is evidenced by the 4IR National Policy and MyDIGITAL Blueprint, resulting in myriads of initiatives to

establish a conducive ecosystem, the Malaysian government is committed to support whole-of-nation digital transformation. The first phase of MyDIGITAL as well as the SME Masterplan 2020 identified key initiatives to boost 4IR technology adoption in Malaysia. In this hypothesis, the total effect between government support (GOVT) as per Table 4-7, GOVT is found to be significant and positively related to ADOPT with point estimate values of $\beta = 0.095$, $t = 1.438$, and $p = 0.075$ at $\alpha = 0.10$. Moreover, between the BCI LL 10% of 0.011 and the UL 90% of 0.180, the interval estimate result for H_7 does not contain zero. In conclusion, both the point and interval estimate results found that there is a significant and positive relationship between GOVT and ADOPT, and thus, the finding supports H_7. This is in line with prior studies (Hasani et al., 2017; Mohtaramzadeh et al., 2018; Owusu-Ansah, 2018) which proved that with willpower and adequate resources (Abu Bakar et al., 2020), government support plays a pivotal role in technology adoption.

In summary, besides H_3 (COST), the total effects for all hypotheses are found to be significant and supported the relationship between individual TOE factors and 4IR technology adoption (ADOPT) among SMEs. Of note is that all significant relationships are supported by both point and interval estimates, and that only H_2 (CPLX) has a negative β value.

4.9.3 Hypothesis testing – Mediation effects

The structural model's mediation effects were then evaluated with the same bootstrapping results. (Table 4-8, Table 4-9) tabulate the results of the mediation effects from H_8-H_{13} hypothesis testing. Based on the interval estimates, all the indirect effects of the hypotheses, except $H_{10,}$ are found to be significant and support TMS mediation relationships between individual TOE factors and 4IR technology adoption

(ADOPT) among SMEs. On the other hand, the direct effects of the hypotheses $H_{9\text{-}10}$ and $H_{12\text{-}13}$ are found to be not significant. Thus, it is concluded that for hypotheses H_9 and $H_{12\text{-}13}$, there exist full mediation effects by TMS between individual TOE factors and ADOPT among SMEs. As for hypotheses H_8 and H_{11}, since their indirect effects are significant, the type of partial mediation effects i.e., complementary partial mediation or competitive partial mediation will be further determined. The individual hypothesis testing results are as follows:

H_8: Top management support positively mediates the relationship between relative advantage and 4IR technology adoption among SMEs

It was hypothesized that TMS positively mediates RA and ADOPT, which means that top management that understands the relative advantages to be gained from the 4IR technology adoption will provide higher TMS in adopting the technology. Based on the evaluation of the indirect effect TMS between relative advantage (RA) and 4IR technology adoption (ADOPT) as per Table 4-8, the point estimate $\beta = 0.117$, $t = 3.386$, and $p = 0.000$ at $\alpha = 0.10$ was significant. Moreover, the interval estimate result for H_8 between the BCI LL 10% of 0.080 and the UL 90% of 0.171, does not contain zero. In conclusion, both the point and interval estimate results found that TMS significantly mediates a positive relationship between RA and ADOPT among SMEs, and thus, the finding supports H_8.

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Table 4-8
Hypothesis testing indirect effects

Hypothesis	Relationship	Std Beta (β)	t-value	p-value	BCI LL 10%	BCI UL 90%	v^2	Decision	
H_8	RA → TMS → ADOPT	0.117	3.386	0.000	0.080	0.171	0.01	significant	supported
H_9	CPLX → TMS → ADOPT	-0.069	2.459	0.007	-0.127	-0.048	0.01	significant	supported
H_{10}	COST → TMS → ADOPT	0.031	0.826	0.204	-0.010	0.077	0.00	not significant	-
H_{11}	SIZE → TMS → ADOPT	0.106	3.001	0.001	0.069	0.163	0.01	significant	supported
H_{12}	COMP → TMS → ADOPT	0.042	1.242	0.107	0.004	0.088	0.00	significant	supported
H_{13}	GOVT → TMS → ADOPT	0.031	1.215	0.112	0.003	0.068	0.00	significant	supported

Note: significance level of $\alpha = 0.10$ or 90% confidence interval with a bootstrapping of 10,000

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Table 4-9
Hypothesis testing – direct effects

Hypothesis	Relationship	Std Beta (β)	t-value	p-value	BCI LL 10%	BCI UL 90%	f^2	Decision	
H_8	RA → ADOPT	0.128	1.782	0.037	0.029	0.214	0.02	significant	supported
H_9	CPLX → ADOPT	-0.145	1.899	0.029	-0.317	0.177	0.02	not significant	-
H_{10}	COST → ADOPT	-0.060	0.680	0.248	-0.163	0.066	0.00	not significant	-
H_{11}	SIZE → ADOPT	0.128	1.688	0.046	0.033	0.226	0.01	significant	supported
H_{12}	COMP → ADOPT	0.078	1.004	0.158	-0.022	0.177	0.01	not significant	-
H_{13}	GOVT → ADOPT	0.064	1.012	0.156	-0.018	0.144	0.01	not significant	-

Note: significance level of $\alpha = 0.10$ or 90% confidence interval with a bootstrapping of 10,000

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As for the direct effects for H_8 referencing Table 4-9, the point estimate $\beta = 0.128$, $t=1.782$, and $p = 0.037$ at $\alpha = 0.10$ was also significant. Furthermore, the interval estimate result for H_8 between the BCI LL 10% of 0.029 and the UL 90% of 0.214, does not contain zero. Hence, both the point and interval estimate results for H_8 found that TMS significantly mediates a positive relationship between RA and ADOPT among SMEs, and thus, the finding supports H_8. Since both the indirect and direct effects for H_8 were found to be significant, and the multiplication of the β values is positive, it can be concluded that TMS has complementary partial mediation effect between RA and ADOPT among SMEs. This proves that high TMS would further magnifies the influence of RA in promoting 4IR technology adoption among Malaysian SMEs. Through blockchain adoption, for instance, SMEs can establish product authenticity through tracking transactions across their supply chain; as well as safeguarding customer information, financial records, electronic payment gateways, and their own intellectual property (IP) rights. This brings forth enhanced accountability, reduction in fraud, and compliance with regulations. Thus, top management that strategically adopted blockchain technology due to its relative advantages could propel their companies to the forefront of the market. In conclusion, the hypothesis testing resulted in a complementary partial mediation that supports findings that TMS positively confounds the relationship between RA and ADOPT.

H_9: *Top management support negatively mediates the relationship between complexity and 4IR technology adoption among SMEs*

Prior empirical studies have proven that complexity bears a negative relationship in 4IR technology adoption. H_9 postulates that TMS would worsen the negative effects in this relationship. Based on the evaluation of the indirect effect TMS between

complexity (CPLX) and 4IR technology adoption (ADOPT) as per Table 4-8, the point estimate $\beta = -0.069$, $t = 2.459$, and $p = 0.007$ at $\alpha = 0.10$ was significant. Moreover, the interval estimate result for H_9 between the BCI LL 10% of -0.127 and the UL 90% of -0.048, does not contain zero. In conclusion, both the point and interval estimate results found that TMS significantly mediates a negative relationship between CPLX and ADOPT among SMEs, and thus, the finding supports H_9.

As for the direct effects for H_9 referencing Table 4-9, the point estimate $\beta = -0.145$, $t=1.899$, and $p = 0.029$ at $\alpha = 0.10$ was also significant. Additionally, the interval estimate result for H_9 between the BCI LL 10% of -0.317 and the UL 90% of 0.177, does contain zero, which means it is not significant. Since there is a contradiction between point estimate and interval estimate, the latter result prevails and that TMS does not significantly mediate the relationship between CPLX and ADOPT among SMEs. Following the indirect effect is significant but the direct effect is not significant, it is concluded that there exists full mediation effect by TMS between CPLX and ADOPT among SMEs. The result proves that if top management does not deem that any course of actions could mitigate and overcome the complexity factor, it would completely hinder the adoption of 4IR technologies.

H_{10}: *Top management support negatively mediates the relationship between cost and 4IR technology adoption among SMEs*

In this hypothesis testing H_{10}, TMS was postulated to amplify the negative effect between cost and 4IR adoption among Malaysian manufacturing and services sectors SMEs. Top management that perceives cost of adoption as unaffordable will not participate in implementing 4IR technology adoption. Based on the evaluation of the

indirect effect TMS between cost (COST) and 4IR technology adoption (ADOPT) as per Table 4-8, the point estimate $\beta = 0.031$, $t = 0.826$, and $p = 0.204$ at $\alpha = 0.10$ was not significant. Moreover, the interval estimate result for H_{10} between the BCI LL 10% of -0.010 and the UL 90% of 0.077, does contain zero. In conclusion, both the point and interval estimate results found that TMS is not significant in mediating the relationship between COST and ADOPT among SMEs, and thus, H_{10} is not supported.

As for the direct effects for H_{10} referencing Table 4-9, the point estimate $\beta = -0.060$, $t=0.680$, and $p = 0.248$ at $\alpha = 0.10$ was also significant. Additionally, the interval estimate result for H_0 between the BCI LL 10% of -0.163 and the UL 90% of 0.066, does contain zero, which means it is not significant. Since there is a contradiction between point estimate and interval estimate, the latter result prevails and TMS does not significantly mediate the relationship between COST and ADOPT among SMEs. Given that both the indirect and direct effects are not significant, it is subsequently concluded that there exists no mediation effect by TMS between COST and ADOPT among SMEs. Given that both hypotheses H_3 and H_{10} for COST were not significant, it is concluded that cost does not influence the Malaysian SMEs decision in 4IR technology adoption.

H_{11}: *Top management support positively mediates the relationship between firm size and 4IR technology adoption among SMEs*

According to Rogers (1995), the larger the size of the organization, the more innovative it would be. This is because the bigger organizations face relatively less resource limitation such as skilled manpower, and are less risk-averse compared to smaller-sized companies. A study interviewed twenty companies in Ireland (Trevor

Clohessy & Acton, 2019) and observed that large companies are more likely to adopt blockchain technology compared to SMEs in a developed country. The study also concluded that managerial-related factors were superior drivers of blockchain adoption. Based on the evaluation of the indirect effect TMS between firm size (SIZE) and 4IR technology adoption (ADOPT) as per Table 4-8, the point estimate $\beta = 0.106$, $t = 3.001$, and $p = 0.001$ at $\alpha = 0.10$ was significant. Moreover, the interval estimate result for H_{10} between the BCI LL 10% of 0.069 and the UL 90% of 0.163, does not contain zero. In conclusion, both the point and interval estimate results found that TMS significantly mediates a positive relationship between SIZE and ADOPT among SMEs, and thus, the finding supports H_{11}.

As for the direct effects for H_{11} referencing Table 4-9, the point estimate $\beta = 0.128$, $t=1.688$, and $p = 0.046$ at $\alpha = 0.10$ was also significant. Furthermore, the interval estimate result for H_{11} between the BCI LL 10% of 0.033 and the UL 90% of 0.226, does not contain zero. Hence, both the point and interval estimate results for H_{11} found that TMS significantly mediates a positive relationship between SIZE and ADOPT among SMEs, and thus, the finding supports H_{11}. Since both the indirect and direct effects for H_{11} were found to be significant, and the product multiplication of the β values is positive, it can be concluded that TMS has complementary partial mediation effect between SIZE and ADOPT among SMEs. Thus, TMS can be seen positively influencing the relationship between firm size and 4IR technology adoption. Evidently in this study, top management of relatively larger Malaysian SMEs was found to increase 4IR technology adoption. They could allocate more resources to invest in the technologies, upskill or reskill their employees, as well as take risks to become more competitive and improve productivity through the technology adopted.

H_{12}: *Top management support positively mediates the relationship between competitive pressure and 4IR technology adoption among SMEs*

In hypothesis H_{12}, the study postulates that top management of Malaysian SMEs would react competitive pressure in the industry by supporting 4IR technology adoption in their companies. Based on the evaluation of the indirect effect TMS between competitive pressure (COMP) and 4IR technology adoption (ADOPT) as per Table 4-8, the point estimate $\beta = 0.042$, $t = 1.242$, and $p = 0.107$ at $\alpha = 0.10$ was not significant. However, the interval estimate result for H_{12} between the BCI LL 10% of 0.004 and the UL 90% of 0.088, does not contain zero, which means it is significant. Since there is a contradiction between point estimate and interval estimate, the latter result prevails. In conclusion, TMS significantly mediates a positive relationship between COMP and ADOPT among SMEs, and thus, the finding supports H_{12}.

As for the direct effects for H_{12} referencing Table 4-9, the point estimate $\beta = 0.078$, $t=1.004$, and $p = 0.158$ at $\alpha = 0.10$ was also significant. Additionally, the interval estimate result for H_{12} between the BCI LL 10% of -0.022 and the UL 90% of 0.177, does contain zero, which means it is not significant. As there is a contradiction between point estimate and interval estimate, the latter result prevails and that TMS does not significantly mediate the relationship between COMP and ADOPT among SMEs. It is subsequently concluded that there exists full mediation effect by TMS between COMP and ADOPT among SMEs. The hypothesis result proves that top management should heed the positive competitive pressure from the industry and move the company to adopt 4IR technologies faster in order to gain competitive advantage and stay ahead.

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H_{13}: *Top management support positively mediates the relationship between government support and 4IR technology adoption among SMEs*

Various researchers have found that top management could leverage on the support provided by the government towards 4IR technology adoption (Hasani et al., 2017; Mohtaramzadeh et al., 2018; Owusu-Ansah, 2018). In this final hypothesis H_{13}, the study is testing if the top management support would intensify the positive effect of government support in 4IR technology adoption among manufacturing and services sectors Malaysian SMEs. Based on the evaluation of the indirect effect TMS between government support (COMP) and 4IR technology adoption (ADOPT) as per Table 4-8, the point estimate $\beta = 0.031$, $t = 1.215$, and $p = 0.112$ at $\alpha = 0.10$ was not significant. However, the interval estimate result for H_{13} between the BCI LL 10% of 0.003 and the UL 90% of 0.068, does not contain zero, which means it is significant. Since there is a contradiction between point estimate and interval estimate, the latter result prevails. In conclusion, TMS significantly mediates a positive relationship between GOVT and ADOPT among SMEs, and thus, the finding supports H_{13}.

As for the direct effects for H_{13} referencing Table 4-9, the point estimate $\beta = 0.064$, $t=1.012$, and $p = 0.156$ at $\alpha = 0.10$ was also significant. Additionally, the interval estimate result for H_{13} between the BCI LL 10% of -0.018 and the UL 90% of 0.144, does contain zero, which means it is not significant. As there is a contradiction between point estimate and interval estimate, the latter result prevails and that TMS does not significantly mediate the relationship between GOVT and ADOPT among SMEs. It is subsequently concluded that there exists full mediation effect by TMS between GOVT and ADOPT among SMEs. From the perspective of this research, it confirms that top

management support increases the positive influence of government support in 4IR technology adoption.

In conclusion, the analysis of mediation effects of TMS between TOE constructs and ADOPT among SMEs indicate that there exists non-mediation for H_{10} (COST); complementary partial mediation type for H_8 (RA) and H_{11} (SIZE), and full mediation effect for H_9 (CPLX), H_{12} (COMP) and H_{13} (GOVT) as tabulated in Table 4-10.

4.9.4 Summary of hypothesis testing

This section concludes the hypotheses testing in this study the structural model assessment based on the path coefficient (β), point estimates (t-value, and p-value) and interval estimates (CI LL and CI UL) significance. Table 4-11, shows a summary of seven direct hypotheses (H_{1-7}) and six mediation hypotheses (H_{8-13}) tested in the study. All hypotheses were significant and supported except for both relationships related to COST, i.e., H_3 in the direct hypothesis, as well as H_{10} in the mediation hypothesis.

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Table 4-10
Hypothesis testing – Typology of mediation effects

Hypothesis	Relationship	Indirect effect Std Beta (β_i)	Direct effect Std Beta (β_d)	(β_i) x (β_d) (+/–)	Decision indirect effects	Decision direct effects	Mediation Typology
H_8	RA → TMS → ADOPT	0.117	0.128	+	significant	significant	Partial complementary
H_9	CPLX → TMS → ADOPT	-0.069	-0.145	+	significant	*not significant*	Full mediation
H_{10}	COST → TMS → ADOPT	0.031	-0.06	–	*not significant*	*not significant*	No mediation
H_{11}	SIZE → TMS → ADOPT	0.106	0.128	+	significant	significant	Partial complementary
H_{12}	COMP → TMS → ADOPT	0.042	0.078	+	significant	*not significant*	Full mediation
H_{13}	GOVT → TMS → ADOPT	0.031	0.064	+	significant	*not significant*	Full mediation

Note: significance level of $\alpha = 0.10$ or 90% confidence interval with a bootstrapping of 10,000

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Table 4-11
Summary of hypothesis testing

H_n	Hypothesis	Significance	Decision
H_1	Relative advantage is positively related to 4IR technology adoption among SMEs.	significant	supported
H_2	Complexity is negatively related to 4IR technology adoption among SMEs.	significant	supported
H_3	Cost is negatively related to 4IR technology adoption among SMEs.	*not significant*	*no relationship*
H_4	Firm size is positively related to 4IR technology adoption among SMEs.	significant	supported
H_5	Top management support is positively related to 4IR technology adoption among SMEs.	significant	supported
H_6	Competitive pressure is positively related to 4IR technology adoption among SMEs.	significant	supported
H_7	Government support is positively related to 4IR technology adoption among SMEs.	significant	supported
H_8	Top management support positively mediates the relationship between relative advantage and 4IR technology adoption among SMEs.	significant	partial complementary
H_9	Top management support negatively mediates the relationship between complexity and 4IR technology adoption among SMEs.	significant	full mediation
H_{10}	Top management support negatively mediates the relationship between cost and 4IR technology adoption among SMEs.	*not significant*	*no mediation*
H_{11}	Top management support positively mediates the relationship between firm size and 4IR technology adoption among SMEs.	significant	partial complementary
H_{12}	Top management support positively mediates the relationship between competitive pressure and 4IR technology adoption among SMEs.	significant	full mediation
H_{13}	Top management support positively mediates the relationship between government support and 4IR technology adoption among SMEs.	significant	full mediation

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4.9.5 Coefficient of determination (R^2)

The resulting R^2 of the model was 0.332, indicating that the predictors explained 33.30 percent of the variance in ADOPT. Based on Section 3.15.4 Coefficient of determination (R^2), an R^2 value of 0.332 indicates substantial predictive power (Cohen, 1988). An R^2 between 0.10 and 0.50 is considered acceptable in social science research but only when some of the predictor variables are statistically significant (Ozili, 2023); such is the case in this study.

Table 4-12
Effect sizes (f^2)

Hypothesis	Relationship (IV-DV)	f^2	Effect size
H_1	RA → ADOPT	0.02	small
H_2	CMPLX → ADOPT	0.02	small
H_3	COST → ADOPT	0.00	none
H_4	SIZE → ADOPT	0.02	small
H_5	TMS → ADOPT	0.11	medium
H_6	COMP → ADOPT	0.01	none
H_7	GOVT → ADOPT	0.01	none
H_8	RA → TMS → ADOPT	0.01	small
H_9	CPLX → TMS → ADOPT	0.01	small
H_{10}	COST → TMS → ADOPT	0.00	none
H_{11}	SIZE → TMS → ADOPT	0.01	small
H_{12}	COMP → TMS → ADOPT	0.00	none
H_{13}	GOVT → TMS → ADOPT	0.00	none

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4.9.6 Effect sizes (f^2)

For assessment of f^2, the study applies the cut-off point defined by Cohen (1988), where the values of 0.02, 0.15, and 0.35 corresponded to small, medium, and large for H_1-H_7, respectively, whereas values lower than 0.02 are considered to have no effect. As for the indirect mediation f^2 for each hypothesis H_8-H_{13}, the values equals to or higher than 0.01, 0.09, and 0.25 corresponded to small, medium, and large, respectively, whereas values lower than 0.01 are considered to be no effect. (Kenny, 2021). Notice from Table 4-12, only TMS has medium full effect size, whereas the indirect mediated effect size, RA, CPLX and SIZE, have small effect sizes, and finally, COST, COMP and GOVT have none.

4.9.7 PLS-based predictive relevance with PLSpredict (Q^2predict)

Further to the suggestion by Shmueli et al. (2019), the study applies $PLS_{predict}$, using PLS-Predict function in SMARTPLS 4 with a 5-fold procedure (k = 5) and r = 5 times to check for predictive relevance. Based on Section 3.15.6 PLS-based predictive relevance, since $Q^2_{predict}$ values are higher than zero, PLS-SEM RMSE is then benchmarked against LM_RMSE. In reference to Table 4-13 (column RMSE PLS – LM), all the indicators of the PLS-SEM RMSE were lower than the LM_RMSE model. In conclusion, the model has a strong predictive power.

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Table 4-13
PLS$_{predict}$ ($Q^2_{predict}$)

Items	$Q^2_{predict}$	PLS-SEM_RMSE	LM_RMSE	*RMSE PLS - LM*
ADOPT1	0.125	1.221	1.392	*-0.171*
ADOPT2	0.206	1.333	1.474	*-0.141*
ADOPT3	0.148	1.152	1.341	*-0.189*
ADOPT4	0.141	1.606	1.842	*-0.236*
ADOPT5	0.138	1.633	1.891	*-0.258*
TMS1	0.274	0.725	0.821	*-0.096*
TMS2	0.280	0.684	0.794	*-0.110*
TMS3	0.275	0.689	0.761	*-0.072*
TMS4	0.267	0.723	0.795	*-0.072*

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4.10 Summary

This chapter focuses on the data analysis and findings performed on this study using SPSS version 28 and SMARTPLS 4 softwares. The collected data went through cleaning and screening steps to detect straight-lining, outliers, and assess normality, non-response bias test, common method variance and multicollinearity. Out of 188 datasets, six datasets were removed due to straight-lining. The data analysis ensued with a total of 182 datasets with PLS-SEM, starting with the measurement model assessments. All outer loadings met the criteria based on the relevant thresholds set for composite reliability, AVE, and discriminant validity. Then, the study assessed the structural model using bootstrapping procedure. Based on the findings, seven direct relationship hypotheses were supported, whereas five out of six mediation effects were supported. The next chapter discusses the findings and the conclusion of this study.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter shall discuss key findings, discussion, and conclusion of the study. The overarching objective of the study is to understand influencing factors of 4IR technology adoption among the Malaysian SMEs. In the preceding chapter, the study also systematically conducted an empirical inquiry on the mediation effects of top management support. This quantitative analysis has been achieved using descriptive analysis and PLS-SEM. First, the chapter brings forth the recapitulation of the study in section 5.2; followed by the summary of the overall results in section 5.3. Next, section 5.4 will discuss the research findings and section 5.5 will deliberate theoretical, methodological, and practical contributions. Following this, section 5.6 covers the limitations of the study, and Section 5.7 presents a number of suggestions for future research. Finally, Section 5.8 concludes this chapter.

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5.2 Recapitulation of the study

Despite the proliferation of 4IR technologies in driving global economic growth, there is still reportedly low adoption rates of these revolutionizing technologies, particularly among the SMEs, in both developing and developed economies. The primary objective of this research is to explore to what extent determinants drive the adoption of 4IR technologies among SMEs. There were seven factors identified in three main contexts, namely technological, organizational, and environmental contexts, to see the direct relationship between the factors and the adoption of 4IR technologies. Subsequently, the study focused on examining the mediating role of top management support in the indirect relationships between the factors and the 4IR technology

adoption. This empirical study gained insight into the understanding how TOE context influence 4IR technology adoption among Malaysian SMEs in the manufacturing and services sectors, as well their strategy profiling vis-à-vis seven research questions. The 4IR technologies in this study consist of AI, big data analytics, blockchain, cloud computing, advanced materials and technology, IoT, as well as other services, platforms (i.e. e-commerce and payment gateway) or infrastructure.

Online questionnaires were emailed to Malaysian SMEs in the manufacturing and services sectors nationwide, and data collected was analyzed using SMARTPLS4 software. Based on the research framework, there are 13 hypotheses, with 4IR adoption as the dependent variable: the technological, organizational, and environmental factors as the independent variables and top management support as the mediating factor on 4IR technology adoption. Following this, the research questions are listed as follows:

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RQ1. To what extent do factors of adoption in the technological, organizational and environmental contexts affect 4IR technology adoption among SMEs?

RQ2. Does top management support mediate the relationships between factors in the technological, organizational and environmental contexts and 4IR technology adoption among SMEs?

RQ3. What is the strategy typology profile of Malaysian SMEs in relation to their adoption trend of 4IR technologies?

5.3 Summary of results

Based on the above-mentioned research questions, this section summarizes the results of the analysis.

First, it was found that six out of the seven constructs under technological, organizational and environmental contexts used in this study affect the 4IR adoption by SMEs in Malaysia. The results of the directional relationship of all constructs supported the reviewed literature. This study corroborated earlier findings that relative advantage of 4IR technologies, the size of the firm, the support from the top management, increased competitive pressure and good government support positively impacted 4IR adoption among SMEs. Complexity, a construct under technological context, has an inverse effect on 4IR adoption and acted as a deterrent in SMEs' decision to adopt 4IR technologies. Contrary to past findings (Al-Qirim, 2007; Ghobakhloo et al., 2011; Mirchandani & Motwani, 2001), cost did not impact 4IR adoption among SMEs. By identifying these factors that drive and the deterrents that dissuade 4IR adoption such as these, key stakeholders, especially the policymakers and companies, will be able to better allocate or pull resources in their organizations to realize economic gains.

As for the mediation effects, top management support played a critical role in 4IR adoption, except for cost. Between individual TOE constructs and 4IR technology adoption, there was non-mediation for cost, complementary partial mediation type for relative advantage and size, as well as full mediation effect for complexity, and both environmental constructs competitive pressure and government support. The non-mediation effect of top management support on cost was intriguing, given that the general rhetoric in the industry, coupled with the finding in the aforementioned

paragraph, that cost of implementation is the biggest deterrent in 4IR adoption among SMEs. This would mean that the mediator top management support is not a factor influencing the relationship between cost and 4IR adoption in this study.

Lastly, the strategy typology of the SMEs in Malaysia revealed an interesting pattern about the archetypes that exist. This study profiled 82 SMEs or 45.1 percent Analyzers; 36 SMEs or 19.8 percent Prospectors; 33 SMEs or 18.1 percent Defenders and finally, 31 SMEs or 17 percent Reactors out of 182 respondents. The Reactor group was substantially larger compared to those empirical studies that did not omit it as a residual strategy (Conant et al., 1990). It was also determined that there were 128 adopters (70.3 percent) out of a total of 182 respondents.

It must be underscored that although strategy typology was not part of the SEM analysis, the descriptive analysis cross tabulation revealed interesting findings between their strategy typology and adoption status. Even though within the respective strategy archetype there were more adopters than non-adopters, surprisingly, Reactor had the highest percentage of adopters at 77.4 percent, whereas Defender had the lowest percentage of adopters at 57.6 percent. It means that more than three quarters of Reactors are adopters despite it being seen as an incoherent strategy type i.e. maintaining strategies even when their environment poses enormous challenges.

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5.4 Discussion of findings

This section discusses the main findings of the work. In this research, there are thirteen (13) hypotheses developed to investigate the relationships between technological, organizational, and environmental contexts and 4IR adoption, as well as the role of top management support as a mediator. Results indicate that the individual constructs

under the technological, organizational, and environmental contexts, except for cost, have a direct effect on 4IR adoption among the SMEs. Likewise, upon testing the top management support mediation effects, the study found significant mediation effects between individual TOE constructs and 4IR adoption among SMEs in Malaysia, except for the technological factor, cost. The results and findings of each factor examined in this study are discussed below to answer all RQ1 and RQ2. Subsequently, findings on RQ3 will be explained.

5.4.1 Findings on Relative Advantage

The results of this study found a statistically significant and positive relationship between relative advantage and 4IR technology adoption among SMEs in Malaysia. It proved that by adopting these 4IR technologies, the SMEs obtain advantages particularly in terms of economic profitability and technological benefits. This is consistent with numerous other studies studying this relationship in the context of information systems and specific 4IR technologies (Ahmad et al., 2015; Alshamaila et al., 2013; Garg & Choeu, 2015; Kumar et al., 2017a; Lutfi et al., 2022; Maroufkhani, Wan Ismail, et al., 2020; Mensah et al., 2021; Mohd Isa & Alenezi, 2022; Park & Kim, 2019; Pathan et al., 2017; Safari et al., 2015; Seethamraju, 2015; Usman et al., 2019; Yaseen et al., 2022). The rationale is that by adopting e-commerce platform which uses AI capabilities, for instance, an SME can become more efficient in terms of work processes, tracking product inventories in real time, providing faster and better after sales service to customers, as well as enhanced supply chain management.

In addition, SME adopters would experience lower cost of doing business from the aforementioned efficiencies, expanding their sales channels virtually, and reaching new customers with minimal cost of advertisements and promotions via e-commerce

platforms. This e-commerce platform adoption benefits not only the retailers and wholesalers in the service sector, but also manufacturers who can effectively opt to diversify vertically into business to consumer markets (B2C). Hence, the relative advantage from adopting 4IR technologies such as e-commerce platform would open up new markets, improve work productivity, lower costs of business, culminating in economic gains. In conclusion, the study found that SMEs stand to gain significantly from 4IR technology adoption; and the more benefits the SMEs gain, the higher the adoption rate of 4IR technologies.

Furthermore, SME manufacturers could also derive relative advantages of 4IR technology adoption through big data analytics capabilities, advanced materials, as well as 3D printing. For example, during the COVID19 pandemic's movement control order, factories producing personal protective equipment (PPE) for frontline medical workers were not allowed to operate although the demand for PPE had skyrocketed. However, leveraging on 3D printing technology allowed companies such as Spectrum Laser Studio in Kepong, Selangor and Admart Solutions, Muar, Johor, to manufacture face shields, intubation shields and ventilators via 3D printers, in lieu of the traditional workers staffing the production lines. Replacing

Another potentially notable relative advantage for manufacturers adopting 4IR technologies lies in the concept of 'servicification'. Conventionally, manufacturers have primarily focused on selling tangible products. By embracing servicification within the manufacturing domain, SMEs can diversify their business models by offering subscription-based services, such as maintenance, repair and overhaul (MRO) in aviation or automotive industries. The implications of servicification are multifaceted, ranging from revenue diversification through a steady flow of

subscription revenue. Moreover, through use of big data analytics, SME manufacturers could offer comprehensive solutions, become more customer-centric, and even collaborate with technology providers to ensure optimal performance of products and predictive maintenance practices.

5.4.2 Findings on Complexity

The adoption of 4IR technologies, such as cloud computing, big data analytics, and AI, poses major challenges for SMEs due to the intricate nature of interconnectivity in these technologies. When a technology exhibits high complexity in terms of usage and demands advanced skills from employees, it tends to deter adoption. Learning advanced systems, understanding new interfaces, and adapting to novel workflows can be daunting for employees. Also, in the initial stages of adoption, these organizations inadvertently impose time constraints on their employees in terms of balancing training sessions alongside their regular work responsibilities. Subsequently, this study's finding is found to be in agreement with several prior empirical studies which demonstrated that complexity is statistically significant and negatively related to 4IR technology adoption (Abbasi et al., 2022; Alshamaila et al., 2013; Awa et al., 2015; Asiaei & Rahim, 2019; Khayer et al., 2021; Lutfi et al., 2022; Maroufkhani, Tseng, et al., 2020; Pathan et al., 2017; Skafi et al., 2020; Wang et al., 2016).

As in any adoption of advanced technologies such as 4IR, the employees of SMEs could be ill-equipped without proper skills to cope with complex user interfaces and a steep learning curve associated with training. In addition to these challenges in reskilling employees, adopting 4IR technologies into the company may require an extensive business process re-engineering. Incorporating new business processes can be quite complicated and involves careful planning and execution. SME adopters

should first identify which functions they are adopting to facilitate easier integration into the company. This ensures that the revised work processes and systems are systematically re-engineered to guarantee compliance with business requirements and overall system consistency and efficiency. Lastly, companies must also consider investments in a sufficient and manageable IT infrastructure with secure systems.

5.4.3 Findings on Cost

Malaysian SMEs are aware that adoption of 4IR technology would help their company gain better market access; provide cost savings, enhance operational efficiency and productivity, ultimately, to improve overall competitiveness. Nevertheless, despite the admittedly large advantages to be gained, the SMEs have limited funds to bear the prohibitive cost of implementing advanced technologies. Per an FMM survey in 2019, Malaysian SMEs viewed automation and technological upgrade mainly as cost rather than investment. Prior studies found varied findings between cost and its relationship with 4IR technology adoption among SMEs. For instance, Choi et al., 2020; Mohtaramzadeh et al., 2018; Ngah et al., 2022; Raut et al., 2017; and Verma & Bhattacharyya, 2017 found cost to be a significant barrier in technology adoption. On the other hand, studies by Abdul Rasheed & Nafiz, 2022; Ghobakhloo et al., 2011; and Mirchandani & Motwani, 2001 proved that cost has no relationship with 4IR technology adoption.

In the same vein, this study also found cost was not a factor in SME adoption of 4IR. It is undeniable that certain 4IR technologies such as blockchain and AI require huge initial investments, and subsequent maintenance. This may have fueled the main rhetoric on the ground that Malaysian SMEs' main barrier to adoption is cost. Simultaneously, Malaysian government is pushing SME digital transformation

through provision of funds, financial subsidies and tax incentives. Thus, SMEs are able to access these provisions to fund cost of 4IR adoption, rendering cost not a contributing factor. Another explanation could be attributed to the diminishing costs of adoption as 4IR technologies are becoming more economical due to democratization and higher economies of scale. Besides, SMEs may have found it to be not as costly as the large companies would, given that the latter may need to replace legacy systems. Despite these developments, the Malaysian government may have inadvertently subsidized the cost of technology adoption excessively. It is therefore timely for the government to reassess the current incentives to optimally balance between the incentives provided compared to the efficacy of the incentives in actually boosting 4IR technology adoption. Otherwise, the government could misallocate fiscal resources in trying to address the slow technology adoption issue among SMEs.

The above arguments can also be extended to another finding in this study, which proved that top management support also does not mediate the relationship between cost factor and the 4IR adoption. This means that Malaysian SME top management believe that cost is manageable, perhaps as the government provides abundance of incentives to push for 4IR technologies to be adopted. To date, there are almost 20 different types of funds, grants or subsidies provided by the Malaysian government, agencies and just as many incubator and accelerator programs (*APPENDIX G and H*). Regardless, top management has no alternatives but to concede to the cost of adoption to ensure SMEs' relevancy and continued growth in the 4IR era, or risk perishing.

5.4.4 Findings on Firm Size

Next, the study looked at the organizational context, specifically on firm size and top management support factors. Unlike other theories, firm size is not considered a

control variable. In this study, it is proven that firm size plays a significant role in influencing SMEs 4IR technology adoption, similar to prior empirical research (AL-Shboul, 2019; Pathan et al., 2017; Trawnih et al., 2021; Yaseen et al., 2021). It means that the smaller SMEs will be less inclined to adopt 4IR. However, given the radical advancement opportunities presented in the 4IR era, SMEs no longer need to grow big before reaching success as evidenced by the startups that have become unicorn companies. According to the Ministry of Science, Technology and Innovation's agency, CRADLE's website, there are currently more than 3,700 active startups in Malaysia compared to just 300 companies a decade ago, particularly using e-commerce and FinTech technologies. CARSOME, for example, is the first Malaysian company that reached unicorn status by breaching USD1 billion valuation in 2021. This startup was established only less than a decade ago in 2015 as the largest integrated car e-commerce platform operating across four Southeast Asian countries, i.e. Malaysia, Singapore, Thailand, and Indonesia. Two of their company values upheld are "*Think big, start small*" and "*Do more with less*" reflect CARSOME's rapid and successful growth from a small startup with one inspection center, to employing more than 2,000 employees now. Edotco became the second unicorn company, providing end-to-end tower services solutions in telecommunications infrastructure services sector. Founded in 2012, it reached USD1 billion in under 10 years.

5.4.5 Findings on Top Management Support

Top management support (TMS) has been found to be instrumental in many empirical studies and has a positive relationship with respect to 4IR technology adoption (Alsharari et al., 2020; Asiaei et al., 2019; A. Lutfi et al., 2022; Maroufkhani, Wan

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Ismail, et al., 2020; J. H. Park & Kim, 2019; Pathan et al., 2017; Skafi et al., 2020; Trawnih et al., 2021; Yaseen et al., 2021; Zamzeer et al., 2020).

In this study, top management was found to be a significant mediator because they are role models, acting like a beacon in signaling behaviors to be emulated by their subordinates within the company. Moreover, top management are the ones formally responsible for strategic behaviors and concurrently communicating those changes, as well as developing company policies and goals that support digital transformation. In reinforcing behaviors in the organization to foster digital transformation culture, top management could set up formal and informal rewards. Ultimately, as top management is in control of allocating human capital resources, it is of utmost importance to build an executive team with relevant management and technical skills. A diverse team with combinations of skills will accomplish a credible and exciting vision of the future. As for SMEs, this executive team could very well be led by members of the top management themselves.

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Top management support was also found to be significant with the highest correlation among the factors (path coefficient = 0.346, t-value = 4.241, and p-value = 0.000), hence, substantiating the instrumental role top management plays in transforming a company digitally. Given the disruptive nature of 4IR technologies, top management has to be strategic in its adoption. It would be risky for top management to invest and incorporate these technologies into existing work functions without any business process improvement, retraining or reskilling employees and a clear future direction from the onset. As small- and medium-sized enterprises with certainly limited resources, a strong and dependable top management support would ensure that these resources are optimized, especially with a knowledgeable top management to navigate

the possible challenges. This further adds to the perplexity of the top management and establishes grounds for the top management support to be tested as a mediating factor in 4IR technology adoption among SMEs.

5.4.6 Findings on Competitive Pressure

Subsequently, the study will discuss the environmental context of the 4IR technology adoption, namely, competitive pressure and government support. Both factors were found to be significant positive influence in 4IR technology adoption among Malaysian SMEs. Competitive pressure is found to be significant, similar to numerous prior studies (AL-Shboul, 2019; Asiaei et al., 2019; D. Kumar et al., 2017a; Maroufkhani, Tseng, et al., 2020; Mohd Isa & Alenezi, 2022; Ocloo et al., 2020; Pathan et al., 2017; Zakari Usman et al., 2019). Empirically, competitive pressure was only found to be non-significant to technology adoption only in cases where the industry studied is not competitive or there is political instability. In the case of Malaysia, these two instances are not relevant and thus, the study did find that stiffer competitive pressure would drive higher levels of 4IR technology adoption among the SMEs. The respondents in this study agree that competitive pressure from the industry players as well as key stakeholders would compel the SMEs to also adopt 4IR technologies. The urgency stems from customers who will be able to find a substitute for any product or service offered by a competitor, thereby threatening the company's current market share and profitability. Moreover, SME suppliers that refuse or fail to adopt 4IR technologies as demanded by their larger enterprise customers or enterprise partners, may become obsolete. The main reason is that these SME non-adopters would be unable to keep up with the demands or become incompatible with advanced 4IR technology systems.

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Another reason arises from the disruptive nature of the technological revolution which could alter the industry structure and affect the competitive landscape. As a result, non-adopter SMEs may suddenly risk being outcompeted by adopters and may not be able to catch up. History has seen how Blockbuster underestimated Netflix, to its detriment. Unicorn companies are also another case of small enterprises and startups leveraging on technologies to grow bigger and become more competitive rapidly, even becoming industry giants eventually. Thus, competitive pressure can be a persuasive factor towards increasing 4IR technology adoption as it can be used strategically to gain competitive advantage by Malaysian SMEs.

5.4.7 Findings on Government Support

Lastly, the study will discuss the relationship between government support and 4IR technology adoption. Past empirical studies found a strong relationship between government support and technology adoption. This study also attests to the positive relationship between government support and the adoption of 4IR technologies by the Malaysian SMEs. Similar findings have been reported in previous surveys such as the empirical studies conducted by (S. Z. Ahmad et al., 2015; Haslinda Hassan et al., 2015; Msomi, 2019; J. H. Park & Kim, 2019; Safari et al., 2015; Skafi et al., 2020; Van Huy et al., 2012). According to Oliveira et al. (2014), regulations are essential to instill the sense of trust necessary for organizations to adopt new technologies, and also facilitate removal of governmental or legislative barriers that can hinder adoption of technologies. This may be attributed to TechReg playing catch up with the rapid advancements in 4IR technologies and cybersecurity threat as a thwarting issue (Dagada, 2024).

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The government of Malaysia has been very instrumental in supporting the adoption of 4IR technologies particularly among SMEs in order to boost GDP through developing the digital economy and related industries. The government support accorded to SMEs are in the forms of formulating national policies and initiatives; establishing funds; funding education and training programs; financial incentives such as funds, grants, and subsidies; and formation of ministerial committees and agencies, as well as linking strong partnerships with technology providers (APPENDIX G and H).

The two main policies launched by the Malaysian government are Industry4WRD in 2018 and 2021, respectively. Moreover, in the SME Masterplan 2012-2020, two of the main focus areas relevant as government support are innovation and technology adoption. It is evident that the Malaysian government is providing the full support in driving 4IR technology adoption, particularly by the SMEs. At this juncture, the researcher would advise caution in the financial incentives provided, as there is evidence of overallocation by the government, to the point that the SMEs will be reluctant to adopt unless some cost is partially or wholly subsidized. Furthermore, the absence of a proper and rigorous program impact evaluation makes it difficult to ascertain which programs yielded successful outcomes (World Bank, 2020).

Finally, the Malaysian government has also established a myriad of incubators and accelerators. The latest public-private-partnership (PPP) initiative called 100 Soonicorns was launched by ScaleUp Malaysia and Proficeo in collaboration with two government agencies, Penjana Kapital and Malaysia Digital Economy Corp Sdn. Bhd. (MDEC) in 2024 (Kementerian Komunikasi Malaysia, 2024). It is a program to groom next generation unicorns to support the nation's aspiration to produce five unicorns by 2025 among startups through founders-supporting-founders syllabus comprising of

structured problem-solving, capacity development sessions, and networking sessions. These Soonicorns will also be showcased as Malaysia's most promising startups to attract potential global investors (Kementerian Komunikasi Malaysia, 2024).

5.4.8 Findings on Top Management Support as Mediator

In terms of the mediator role of top management support (TMS), the study has proven it to be significant in 4IR technology adoption among SMEs in Malaysia, although scant studies have examined it as mediator variable (Abu Hassan et al., 2023; Teh et al., 2024). This is mainly due to top management having the power and authority to decide whether to adopt the 4IR technologies for strategic reasons and subsequently allocate company resources appropriately. The study resulted in all predictor variables, except for cost, being found to be mediated by top management support. Specifically for technological context, top management support would be able to leverage on relative advantage, while putting sufficient resources towards managing complexities 4IR technologies to push the SMEs to embrace adoption.

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To ensure the success of the company's digital transformation, top management should start small by focusing on investing in functions that could first help build a business case for 4IR adoption. For example, the SME can start by introducing an e-payment gateway option to customers, subscribe to an e-commerce platform with just a couple of products, or using mobile apps to automate its payroll function. This way, the management could experience a small win, yet experiment with tolerable risk levels and mitigate the complexities of the technology adoption. Furthermore, top management plays a vital role in managing complexity of the 4IR adoption by taking necessary steps to employees reskilling or upskilling. As a result, the top management will obtain the buy-in from the rest of the company to adopt 4IR technologies by

showing that the company would benefit from cost savings, higher revenues, increased market share, or improved productivity levels.

Next, the organizational context, size. Being an SME in country like Malaysia should work in favor of the enterprise because top management could capitalize on numerous government support provided. Competent top management could potentially use its small size to expedite digitally transforming the company. As discussed earlier, SMEs may have the advantage of being more agile as there is no legacy systems issue. Moreover, there are relatively smaller number of employees to be upskilled re-skilled, and larger companies may provide support to assist SME suppliers' technology adoption. Top management such as CARSOME are business savvy such that even when the company is still small in size, they have the vision and mission to deliver big results and do more with less by optimizing resources strategically.

Finally, in the environmental context, the top management could understand the risks and negative effects from the presence of strong competitive pressure and thereby fast-track the company's adoption of 4IR technologies. It appears that top management of SMEs have no choice but to acquiesce to the competitive pressure in the digital transformation, or risk their survival as other SMEs adopt. Customers are also quickly adapting to the benefits of purchasing and consuming through e-commerce platforms, and thus, SMEs must digitally transform to ensure revenue stream. The study also proves that strong top management support would amplify the positive support from the government to encourage 4IR technology adoption. In conclusion, it is irrefutable that top management mediates determinants in TOE's environmental context, and any effort to effectively boost 4IR technology adoption among SMEs must be driven by the top management.

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5.4.9 Findings on Strategy Archetypes

In this section, the SME respondents' strategy archetypes will be discussed, particularly with respect to their 4IR adoption trends. The mediating role of top management support adopting Reactor strategy typology could shed light into the phenomenon of low adoption level among the Malaysian SMEs. More specifically, in this study, out of 182 respondent SMEs, there were 82 Analyzers (45.1 percent); 36 Prospectors (19.8 percent); 33 Defenders (18.1 percent) and 31 Reactors (17 percent). Compared to previous studies, it is notable that this study profiled a considerably higher number Reactor SMEs that participated; almost comparable to that of Defender and Prospector archetype groups. Typically, only a very small number of Reactors are found since it is a residual strategy, which means that only when the companies are unable to adopt the other three strategy archetypes. It is characteristic of Reactors to implement strategies incoherently to the challenges faced (Miles et al., 1978) or slow in reacting to change (Parnell et al., 2015), indicating deficient management skills.

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As for the comparison between adopters and non-adopters, similar to prior studies, Analyzers make up the majority of this study's 128 SME adopters at 61 companies (47.66 percent). The Analyzer strategy archetype is admittedly challenging to SMEs, as these companies have limited resources. The strategy involves a complex balancing act between being innovative to strive for higher profitability with the needs for operational efficiency and market stability. Among the adopters, there are 24 Prospectors (18.75 percent) and 24 Reactors (18.75 percent). Meanwhile, Defender has the least number of 4IR technology adopters at 19 SMEs (14.84 percent). Prospectors are innovators that exploit innovation for new market opportunities, whereas Defenders are known for prioritizing efficiencies. This could explain the motivation for adoption of 4IR technologies between these two strategy archetypes.

It must be reiterated that although strategy typology was not part of the SEM analysis, the descriptive analysis revealed interesting findings between their strategy typology and adoption status. Even though within the respective strategy archetype groups there were consistently more adopters than non-adopters, Reactor had the highest percentage of adopters at 77.4 percent, whereas Defender had the lowest percentage of adopters at 57.6 percent. Based on the Miles and Snow's (1978) categorization of the archetypes, Reactor is in fact a residual strategy whereby top management responses to the adaptive cycle are fragmented and incoherent at best. In other words, this is the least effective strategy and usually lead to poor performance. An organization defaults to Reactor strategy because the management continues to uphold current incoherent strategy and structure in the face of a tremendous change in its environment. Reactor strategy is not viable for the company, as it often operates in survival mode, lacking proactivity, which will then lead to instability and poor performance. Basically, Reactor will only change when they have no more options to pursue. Following this line of reasoning, Reactors should not have been the archetype that consist of majority of adopters of 4IR technologies in the group.

Nonetheless, policies such as Industry4WRD, MyDIGITAL, and PENJANA are designed to support SMEs by offering training, matching grants, subsidized financing programs and IT expertise through appointed technology service providers (TSPs). This could explain the reason there are more adopters within the Reactor group, as they too have access to government assistance as aforementioned. It follows that eventually, they would be able to realign their strategy into one of the more robust typologies; be it Defender, Prospector or Analyzer. Moreover, the appointed TSPs are instrumental in matching a suitable type of 4IR technologies with the SMEs, depending on their sector, industry, and locality, as well as the functions the

technology would be adopted for. For instance, if an SME is in the wholesale and retail subsector and located in a rural area, a TSP could recommend the company to adopt an electronic payment gateway and an e-commerce platform such as Shopee, which already has AI services capabilities. This way, SMEs will adopt e-commerce for the purposes of diversifying its sales channel as well as expanding its market access via online channels. The adoption of e-payment gateway will also provide ease of sales transaction via cashless in-store purchases, where access to ATM machines and banks are limited in the rural areas.

5.5 Contributions of the study

In this section, the researcher will discuss the contributions of the research to the body of knowledge in several ways, i.e., theoretical and methodological contributions to academics, as well as practical contributions to the industry players and policymakers.

5.5.1 Theoretical Contribution for Academics

The research advanced the understanding of the factors of 4IR technology adoption among SMEs in a developing country, i.e. Malaysia, using DOI theory and TOE framework as the underpinning theories, thereby empirically validated the integrated research framework. The study exhibited the method of selection theories are important to suit the unit of analysis being studied.

Through the integration of two underpinning theories DOI theory and TOE framework, the research contributed to theory development and technology adoption body of knowledge that would prove useful in terms of implementing 4IR technology adoption for academics, policymakers, and industry players. More specifically, government and companies will be able to understand factors of adoption and better

able to allocate resources optimally in support of the digital transformation initiatives in their respective organizations.

Moreover, this study empirically established the drivers and barriers of 4IR technology adoption organizations in technological, organizational, and environmental contexts that are unique to Malaysian SMEs. For example, the technological factor, cost, was found to have no relationship with 4IR technology adoption; nor was it a factor in the mediation by top management support. As SMEs with limited financial resources, it was a surprising finding. Nevertheless, it could be explained by the fact that the Malaysian government has provided expansive grants, tax incentives and more importantly, access to financing such as soft loans for SMEs looking to adopt 4IR technologies.

Where prior studies have focused on large companies, this study has chosen to focus on the SMEs in the manufacturing and services sectors in a developing country. In particular, the findings of the study about which factors are important and will help drive the adoption of 4IR technologies, bearing in mind the limited resources that SMEs have. There is a significant need for focusing on this segment as prior research conducted on large companies cannot be generalized, even more so given the differing context of the economic development studied hitherto.

Another theoretical contribution made by the study is to prove that top management support is both a significant determinant and a mediator in the relationship between individual TOE factors and 4IR technology adoption. The introduction of top management support as a mediator variable sets apart the study from extant technology adoption studies. This study contributes to the growing body of technology adoption

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research by conclusively demonstrating that top management support is not merely a determinant, but a significant mediator in 4IR technology adoption among Malaysian SMEs. It was conclusively found that all TOE factors are partially or fully mediated, except for cost. This means that in the study, cost did not have a relationship in both direct and indirect relationship in 4IR technology adoption. Moreover, it also further advanced the body of knowledge through better understanding of how crucial the role of top management support is in adopting 4IR technologies to improve firm's productivity and gain competitive advantage, regardless of firm size.

Finally, Miles and Snow (1978) strategy typology was the third underpinning theory used to profile the SMEs to shed light on adopter behaviors with respect to their strategy profiles. First, unlike previous studies thus far, the strategy typology employed self-typing method as its measurement items (Conant et al.,1990) adapted and translated to the local context. Second, using self-typing revealed a much higher proportionate of the SMEs in Malaysia as reactor-type, a residual strategy typology whereby the business strategies employed by the firm are not aligned with its goals and objectives to remain competitive. On the other hand, the profiling concurs with other studies in that the biggest archetype is the Analyzer-type, which means majority of the Malaysian SMEs are able to balance the flexibility and innovativeness of a Prospector while concurrently protect its niche domain to maintain market share like a Defender. Regardless, the study also found that despite their strategy typology, adopters across all four strategy typologies embraced 4IR technologies that are suited to either industry-specific or generic administrative functions.

5.5.2 Practical Contributions for Practitioners

The study aims to inform the industry, particularly the SMEs, to expedite their adoption of 4IR technologies such as AI, blockchain, cloud computing in e-commerce platforms. Foremost, the study showed the crucial role that top management plays in supporting the adoption of 4IR technologies in their company. It means that in an SME, its top management must be knowledgeable and strategic about adopting technologies for their company, despite the complexity of those technologies and limited resources available. As a matter of fact, these challenges should drive top management to manage their resources optimally. Fortunately, 4IR technologies and AI-based platforms in mobile and cloud-based are increasingly more accessible, easier to use and affordable. Besides, the government is also playing their role in supporting SMEs via National 4IR Policy, MyDIGITAL Blueprint, SME Masterplan 2020 and National AI Policy that lay grounds for initiatives, financial incentives, reskilling and upskilling programs necessary to boost adoption.

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In addition, in a smaller organization, top management plays a role in managing the initial adoption phases by focusing on administrative functions such as payroll. Another option is to expand their sales channel into e-commerce platforms. This would ensure minimal risks and disruption to company operations, to slowly build a successful business case for technology adoption. Meanwhile, the SMEs can capitalize on funding and financial incentives offered by the government to further optimize their investments in acquiring the technologies.

Top management support definitely proved crucial in the adoption study and relates to the profiling of business strategy. The motivation also stemmed from the VUCA environment, which was coincidentally exacerbated further by the COVID19

pandemic during the period of the study that proved detrimental to the world economy and lives in general. Paradoxically, the disruption from the pandemic expedited the rate of 4IR technology adoption such as AI-powered e-commerce for the sake of continuity of sales channels, and e-health mobile apps to help track, schedule and monitor vaccination initiatives. Hence, the strategy profiling in this study will provide greater insight into this relationship, as each strategy type would respond differently to various factors of adoption. For example, a Defender strategy is more conservative and protective of their markets. Hence, to obtain buy-in from their top management, it may be best to show business cases that enables them to maintain their market share and cost savings. In the same vein, the government would need to cater to a different approach to incentivize adoption among Defender SMEs as opposed to a Prospector or an Analyzer strategy-types.

Many countries face challenges to get the majority of their SMEs to embark on the digital transformation through 4IR technology adoption. With the population of SMEs making up more than 90 percent worldwide, their adoption of 4IR technologies would definitely contribute towards higher productivity and comparative advantage to the nation. Thus, the study will prove useful and relevant to other economies, irrespective of their economic development status. As policymakers, understanding which factors that drive adoption of 4IR technologies would inform them how to implement the policies and initiatives, as well as allocate fiscal resources optimally. Ultimately, this would benefit the Malaysian economy as a whole towards becoming a developed country, and other nations in expediting SME 4IR technology adoption.

This study found that top management support does not influence the relationship between cost and 4IR adoption, a surprising result given SMEs' limited resource. A

potential explanation is the Malaysian government's extensive financial support for 4IR adoption, which may diminish the perceived impact of cost. As exhibited in the list of financial support provided over the past eight years, there are almost twenty that has been compiled funds, grants and subsidies to encourage Malaysian SMEs to embrace technology adoption between 2017 and 2025 (Appendix G) and about as many incubator and accelerator programs (Appendix H). This warrants a reassessment of funding and subsidies to optimize resource allocation and ensure a return on investment in SME 4IR technology adoption. It also shows redundancies between government agencies in providing similar funding allocations for the SMEs, further exacerbating issues in managing funds. Implementing continuous monitoring and evaluation systems is crucial in order to assess the efficacy of fiscal resource allocation. Furthermore, addressing potential redundancies in funding and intended recipients across agencies could improve efficiency. Differentiating funding based on adoption stages, such as dedicated support for training and skills development areas where SMEs often lack capacity is essential. Policymakers must ensure resources are allocated effectively to drive meaningful 4IR adoption.

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5.6 Limitations of study

Despite the contributions made by the study to the body of knowledge, there exists certain limitations. One such limitation of this research examined the adoption stage without extending it to the post-adoption stages of 4IR technologies as well as the impact of its implementation on the SMEs' financial and non-financial performances. In addition, the study was conducted cross-sectionally instead of longitudinally, which would be better suited to mediation analysis. This method also does not allow for causal inferences across time, which could otherwise capture the dynamics of adopters

and non-adopters. A longitudinal follow-up study would allow for more profound insights into technology adoption. Likewise, the methodology employed was quantitative, although the researcher did include a free-form section to gain qualitative general feedback, explanations or to comment about the factors included in the study, particularly to explain reasons for non-adoption. A quantitative study in a TOE framework proved difficult as there are quite a ubiquitous number of factors that could potentially be explored in technology adoption studies. Thus, the study relied heavily on the literature review to narrow down the key factors. Another limitation was due to the responses being limited to a single source respondent per company, which could potentially bring about biased responses from one person to another depending on their position within the same company.

There were very few respondents from the medium-sized manufacturing sector, albeit expected. The sampling frame was from a list of SMEs obtained from DOSM generated list and MPC databases, which was compromised due to the impact of post-COVID19 movement control order. As a result, many SMEs were affected and even went out of business that influenced the overall response rates. Thus, generalization of the study for this group of SMEs might be limited and cautionary.

Finally, the study covered two main sectors of the economy, i.e. the manufacturing and service sectors. The disparity in the respondent profiles, particularly due to the low number of respondents from medium-sized enterprises, limited the research such that the comparison between the sectors was not possible. Besides, within each sector, there were a lot of sub-sector groupings. It is fathomable that one sub-sector could differ, depending on the nature of their industry and the types of 4IR technology that would be adopted. Also, statistically, although 182 usable responses are more than

adequate to run a structural equation modelling, it was insufficient to run a robust multigroup analysis (MGA) between the type of strategy typology and the 4IR technology adoption to see its moderation impact. The limitations aforementioned prompted an impetus for future studies, which will be addressed in the next section.

5.7 Suggestions for Future Research

This section will reflect on suggestions for future studies that would further understanding and promote complementary findings for theory development and methodology in the field of 4IR technology adoption among SMEs.

This study integrates two different theories, namely, DOI theory and TOE Framework. For futures studies, it is recommended to integrate other management theories such as the Institutional Theory of Information Technology – INT (DiMaggio & Powell, 1983). In the institutional theory, there are three distinct, but interdependent pressures termed as mimetic, coercive, and normative pressures for researchers to investigate technology adoption and diffusion. Coercive pressure is comparable to the environmental context in TOE framework, but it specifically refers to the informal and formal pressures from the environment exerted by government and marketplace. Mimetic pressure exists when there is a problem within the organization such that the firm would mimic others in the industry. Finally, normative view emphasizes the cultural aspects or shared norms among the actors in the social network. Given this approach, future studies could augment the research framework within the field of on 4IR technology adoption by investigating other factors.

One more way to extend the study is to incorporate other variables from the TOE framework, such as trialability in the technological context, organizational readiness

in the organizational context, and infrastructure in the environmental context. For instance, trialability could be a strong determinant as the latest 4IR products offerings also include pay-per-use or trial basis subscription which could overcome obstacles in adoption of 4IR technologies such as blockchain or big data analytics which require high capital outlay initially.

Future studies in 4IR technology adoption could also benefit greatly by including Miles and Snow's (1978) theory on strategy typology as a moderator in the research framework. The interplay between the business strategy of the individual archetypes Prospector, Defender, Analyzer and Reactor could be studied by using a multigroup analysis using PLS-SEM. This would explain why some SMEs of similar characteristics such as size and industry do adopt 4IR technologies, but some do not. For example, a Prospector-typed SME would adopt 4IR technologies given that its business strategy is to focus on finding and exploiting new products and market opportunities (Miles et al., 1978, p. 551).

Taking into consideration that this study is a quantitative one, future studies should apply mixed-method for their methodology approach. As mentioned in the 5.6 Limitations of study section, a qualitative method would improve curating factors in the TOE framework prior to it being tested in the quantitative part. For example, in a focus group discussion, the researcher could administer semi-structured interview sessions to gain more insight and in-depth understanding of the factors in question. Also, a survey can be carried out as longitudinal research to explicate factors that influence 4IR technology adoption as a process, which is temporal in nature and could happen in stages. Moreover, it will also facilitate a more robust mediation analysis. Another way is to utilize proportionated stratified sampling method to compare 4IR

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adoption between small and medium enterprises, as well as between manufacturing and services sectors. Finally, a comparative study on 4IR technology adoption between SMEs in developing versus developed countries could broaden the generalizability of study findings.

Another worthwhile future research would be to use Importance-Performance Matrix grid analysis (IPMA) in PLS-SEM. IPMA is useful to extend findings by prioritizing initiatives or measures that the Government should implement first, based on its importance to the target groups and could improve performance. In this study, IPMA grid may show that cost is a "possible overkill" category, which would explain the factor's non-existent relationship with 4IR technology adoption. If so, the government could effectively reallocate fiscal resources into other areas such as reskilling or upskilling programs for the workforce.

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5.8 Concluding Remarks

The crux of the study is the issue of low levels 4IR technology adoption among SMEs in the midst of revolutionary and disruptive era of digital transformation. Being resource-constrained, both the government and companies must grasp which determinants of 4IR technology adoption are crucial towards higher productivity and economic advancements. As the most important macroeconomic sectors, manufacturing and services, particularly among SMEs that represent 90 percent of enterprises globally, cannot afford to the consequences of falling behind in such a competitive world. This study uncovers a few revealing findings in the context of SME 4IR technology among SMEs. It challenges the assumption of TOE framework and proves that top management support serves not just a determinant, but more importantly, a critical mediator in the context of SMEs' 4IR technology adoption.

First implication is that when top management is convinced of the relative advantage in 4IR technologies, adoption will happen through mobilization of resources to harness the benefits and improve productivity as well as economically. Second, regarding complexity, a strong management will mitigate technical and operational challenges by improving employee capability development, taking advantage of cheaper subscription-based services and platforms with trialability, plug-and-play functions, and after-sales support, and promoting a culture of innovation. Third, despite size limitations, top management could capitalize on agile decision-making, efficient resource prioritization, and leadership clarity, all of which help smaller firms engage meaningfully with digital transformation. Fourth, in the presence of competitive pressure, top management provides the impetus to respond proactively rather than reactively, seizing strategic opportunities and trendy e-commerce and social media purchasing trends. Fifth, government support proves most effective when SME leaders are aware of and actively leverage incentives, grants, and advisory services to boost adoption of 4IR technologies.

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These findings reinforce the argument that top management support is essential to bridge the gap between external enablers and internal execution. Therefore, to effectively push 4IR adoption, government programs need to develop capabilities of the top management in terms of digital skills, digital leadership and strategic management skills specifically targeted towards SMEs. For instance, as the study proved that complexity is a deterrent to 4IR technology adoption among SMEs, policymakers could appoint technology providers that would guide and support the SMEs throughout the process. More engagements with the SME groups could shed light on the issues that they face with the current programs or appointed technology

providers to fine-tune initiatives and allocation of resources accordingly to convert the non-adopters and laggards.

As demonstrated in this study, cost neither influences adoption directly nor through the mediating role of top management support. This raises a critical implication, which is the focus on financial constraints as the main barrier may be overstated. Instead, the slow adoption rate points to deeper issues in SMEs, such that even when financial resources are available, SMEs may lack the internal drivers necessary to translate support into action. Therefore, policies should place greater emphasis on enhancing managerial capability, fostering digital leadership, and institutionalizing long-term strategic planning among SMEs.

The findings also reveal important behavioral insights that relate to the strategy typology profile of the SMEs. Malaysian SMEs predominantly self-selected into the Analyzer strategy archetype, which seek to balance efficiency and innovation simultaneously. For SMEs, the Analyzer strategy is more complex and difficult to operationalize since the strategy requires agility in adapting to dynamic market conditions, hence it requires ample financial and non-financial resources.

Moreover, the unusually high number of Reactor-type among Malaysian SMEs, which is rarely observed in existing empirical literature, raises concern. A general pattern of reactionary decision-making and a tendency to pursue digitalization initiatives without clear strategic direction are typical characteristics of Reactor archetype. Many of the SMEs appear ready to adopt 4IR technologies but without clear strategic direction, often reacting to available external funding or pressure rather than long-term planning. These SMEs may seem ready to implement adoption, but their profile could explain

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why even well-intentioned initiatives and financial subsistence by government and agencies to counteract high costs factor do not gain traction. Thus, government must be compelled to review the existing programs and financial subsistence to reallocate funds towards developing SME management in terms soft management skills, as well as implement a robust monitoring, evaluation and performance assessments mechanisms to mitigate implementation failure.

Ultimately, the study signals a larger policy implication. When cost is no longer the dominant barrier, adoption becomes less about affordability and more about strategic management and leadership capabilities. These insights are not limited to government support in boosting adoption of 4IR technologies, but are relevant in other industries or areas where similar programs and financial subsistence are also provided, e.g. other SME development areas such as in *halal* development, vendor development programs, pharmaceuticals, semiconductors, financial services, and energy. For Malaysia to unlock the full potential of its SMEs, a more integrated, pragmatic, evidence-based and performance-driven policy implementation approach is required.

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APPENDICES

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Appendix A

Questionnaire (English)

SME SURVEY: 4IR (FOURTH INDUSTRIAL REVOLUTION)

TECHNOLOGY ADOPTION AND FIRM STRATEGY TYPOLOGY

YBhg. Dato'/YBrs. Dr./Sir/Madam,

We are pleased to inform you that your company has been nominated as a respondent in this academic research. The study aims to seek understanding about factors of adoption of the 4IR technologies (the Fourth Industrial Revolution) and firm strategy typology among small and medium enterprises (SMEs). **SMEs includes companies that employ more than 5 full-time employees.** It should take approximately 15-20 minutes to complete.

The respondents should preferably be a member of **your management team**. Your responses to the questionnaire are **STRICTLY CONFIDENTIAL** and will not be linked back to you or your company. The responses will be used in aggregate and be limited to analysis of the study only.

Your participation and prompt response are highly appreciated, not to mention being crucial towards improving the nation's 4IR and SME policies. Should you wish to withdraw from the study, or have any questions or require any clarification related to the study, please contact me via my email at azrin_adlina@oyagsb.uum.edu.my. Thank you.

Yours Sincerely,

Azrin Zainol PhD Candidate
School of Technology Management & Logistics
Universiti Utara Malaysia (UUM)

PART I: DEMOGRAPHICS - RESPONDENTS

This part of the questionnaire collects demographic information about the respondent. Please choose relevant answers.

1. Please provide your company name:
   _____

2. Please enter email address (optional): _____

3. Please state your current position(s) in the company (maximum of 2 choices):
   - Owner
   - CEO/Managing Director
   - Senior Management/C-Suite Executive/Partner
   - Head Of Department/Manager
   - Executive Level
   - Secretarial/Administration

4. Please state your tenure at the current position:
   - Less than 3 years
   - 3 – 5 years
   - 6 – 10 years
   - 11 – 15 years
   - More than 15 years

5. Have you had meaningful involvement in the development of your company's strategy making activities?
   - Yes
   - No

6. Please specify your highest academic qualification:
   - School certificate
   - Diploma/Professional certificate
   - Bachelor's degree
   - Master's degree
   - Doctorate degree

7. Please state your gender:
   - Male
   - Female

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PART II: FIRM STRATEGY TYPOLOGY

For PART II, kindly CHOOSE ONE of the statements that best describes your company.

1. In comparison to the competitors, the products/services we provide to our customers are:
    - Well focused, stable, and consistent throughout the company and the markets.
    - Fairly stable (unchanged) in several units/departments/ markets but innovative in others.
    - More innovative, continually changing, and broader in nature.
    - In a state of transition, and largely based on responding to opportunities or threats from the market or environment.

2. The amount of time and resources our company spends on monitoring changes and trends in the market can best be described as:
    - Lengthy: we continuously monitor the market.
    - Average: we spend a reasonable amount of time monitoring the market.
    - Minimal: we hardly spend much time monitoring the market.
    - Sporadic: we sometimes spend a great deal of time but at other times we spend little time monitoring the market.

3. In contrast to the competitors, our image in the market is that we:
    - React to opportunities or threats in the market to maintain or enhance our position.
    - Have a reputation for being innovative and creative.
    - Adopt new ideas and innovations, but only after careful analysis.
    - Offer fewer, selective products/services but are high in quality.

4. Compared to other companies, the increase in or losses in demand for our products/services is mainly due to our practice of:
    - Concentrating more on fully developing the markets that we currently serve.
    - Assertively penetrate deeper into the markets that we currently serve, but also adopting new products/services after a very careful review of their potential.
    - Aggressively entering new markets with new products/ service.
    - Responding to the pressures of the market by taking minimal risks.

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5. One of the most important goals in this company is our dedication and commitment to:

- Ensure that people, resources & equipment required to develop new products/services and enter new markets are available and accessible.
- Carefully analyze costs in revenue to keep it under control & selectively develop new products/services or enter new markets.
- Keep costs under control.
- Ensure we guard against critical threats by taking any actions necessary.

6. Compared to other companies, the competencies (skills) of our management can be best characterized as:

- Fluid: their skills are related to the short-term demands of the market.
- Broad and entrepreneurial: their skills are diverse, flexible, and enable change.
- Analytical: their skills enable them to both identify trends and then develop new product/service offerings or markets.
- Specialized: their skills are concentrated into one, or a few, specific areas.

7. The one thing that protects our company from competitors is that we are able to:

- Do a limited number of things exceptionally well.
- Carefully analyze emerging trends and adopt only those with proven potential.
- Consistently develop new products/services and new markets.
- Respond to trends although they may have only moderate potential of happening.

8. Compared to other companies, our management staff tends to focus on:

- Developing new products/services and expanding into new markets or market segments.
- Analyzing opportunities in the market and selecting only those opportunities with proven potential, while protecting a secure financial position.
- Maintaining a secure financial position through cost and quality control measures.
- Activities or business functions which most need attention given the opportunities or problems we are currently facing.

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9. Compared to other companies, we prepare for the future by identifying:

- the best possible solutions to problems or challenges that require immediate attention.
- trends and opportunities which can result in the creation of product/service offerings that are new to the industry or can reach new markets.
- industry trends that our competitors have proven to possess long-term potential, while solving problems related to our current product/service offerings and our customer needs.
- Problems which, if solved, will maintain, and then improve our current product/service offerings and market position.

10. Compared to our competitors, the organization structure of our company is:

- Functional in nature (i.e. By department – marketing, accounting, etc.).
- A hybrid structure (i.e. Mainly functional in nature, but for newer or larger product/service offering areas, categories of product /service or market-oriented).
- Based on categories of product/service or market-oriented.
- Continually changing to enable us to meet opportunities and solve problems as they arise.

11. The procedures our company uses to evaluate performance are best described as:

- Decentralized and participatory; encouraging many organizational members to be involved.
- Hybrid; centralized in more established product/service areas, and more participatory in newer product or service areas.
- Highly centralized and primarily the responsibility of senior management.
- Heavily oriented towards those reporting requirements which are urgent.

PART III: COMPANY PROFILE

Questions in this part relate to your COMPANY PROFILE. Please choose an appropriate answer.

1. Ownership of your company as registered with SSM (Companies Commission of Malaysia):

- Private limited company
- Sole proprietorship
- Partnership
- Limited Liability Partnership (LLP)

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2. Number of years since the company was established:

- Less than 3 years
- 3 – 5 years
- 6 – 10 years
- 11 – 15 years
- More than 15 years

3. Choose company (Headquarters - HQ) location:

- Johor
- Kedah
- Kelantan
- Melaka
- Negeri Sembilan
- Pahang
- Perak
- Perlis
- Pulau Pinang
- Sabah
- Sarawak
- Selangor
- Terengganu
- WP Kuala Lumpur
- WP Labuan
- WP Putrajaya

4. Choose company's area of locality:

- Urban
- Suburban
- Rural

5. Main industrial sector of your company: (Choose either manufacturing or services):

- Services
- Manufacturing

6. If **SERVICES** is your company's MAIN industrial sector:

- Arts, Entertainment & Recreation
- Education
- Food & Beverages and Accommodation
- Healthcare
- Information & Communication Technology (ICT)
- Professional (Finance, Insurance, Business Services) & Real Estate Activities
- Transportation & Storage
- Utility/Energy
- Wholesale & Retail Trade

7. Annual Sales Turnover (service):

- Between RM300,000 and RM3 Million
- Between RM3 Million and RM20 Million

8. Number of full-time employees (service):

- Between 5 and 30 full-time employees
- Between 30 and 75 full-time employees

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9. If MANUFACTURING is your company's main industrial sector:

- Agro-Based and Food Products
- Cement & Building Material Food Industries
- Electrical And Electronics
- Furniture And Wooden Products
- Geometric & Electrical Industries and Metal Industries
- Machinery And Equipment
- Resource-Based Industries
- Manufacturing-Related Services (MRS)
- Textiles And Apparel

10. Annual Sales Turnover (manufacturing):

- Between RM300,000 and RM15 Million
- Between RM15 Million and RM50 Million

11. Number of full-time employees (manufacturing):

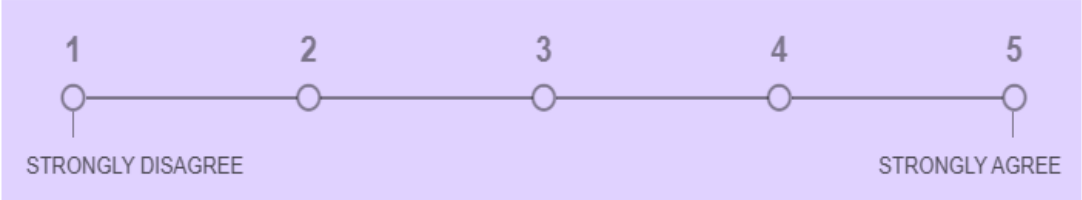
- Between 5 and 75 full-time employees
- Between 75 and 200 full-time employees

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DEFINITION OF 4IR TECHNOLOGIES in this study refers to these specific technologies as identified in the Fourth Industrial Revolution Policy in 2021. The 4IR technologies such as AI, Big Data Analytics, Blockchain, Cloud Computing, e-commerce platforms, etc.

TECHNOLOGY ADOPTION in this study refers to the stage in which a technology is selected for (future) use by a company either through ownership or subscription.

Please answer by selecting one number in the interval Likert scale of 1-5 and labelled Strongly Disagree [1], Disagree [2], Neutral [3], Agree [4], and Strongly Agree [5].



PART IV: TECHNOLOGICAL CONTEXT

SECTION A – RELATIVE ADVANTAGE

Glossary: relative advantage is "the degree to which 4IR technologies are perceived as being better than the idea of any other technology it supersedes". Economic profitability, social prestige, and benefits of technology are expressed as the degree of relative advantage.

Please indicate your actual opinion about the relative advantage factor of 4IR technology (refer definition at top page) adoption or its potential effects on your company.

A1. 4IR technology improves our company's quality of work

A2. 4IR technology makes our work more efficient.

A3. 4IR technology lowers our costs of doing business.

A4. 4IR technology improves our customer service.

A5. 4IR technology attracts new sales to new customers or new markets to our company.

A6. 4IR technology identifies new product/ service opportunities for our company.

SECTION B – COMPLEXITY the more complex, the lower the adoption.

Glossary: Complexity is the degree to which 4IR technologies are perceived as being relatively difficult to understand and use.

Please indicate your actual opinion about the complexity factor of 4IR technology adoption (refer definition at top page) and its potential effects on your company.

B1. The skills necessary to use 4IR technology are too complex for our employees.

B2. The skills needed to implement 4IR technology are too complex for our company.

B3. Integrating 4IR technology into our current work practices will pose a challenge.

SECTION C – COST

Glossary: Cost *(of adoption) depends on the technology and includes setup costs, hardware, software, recruitment, training costs; as well as indirect costs such as maintenance costs, switching cost and administrative costs.*

Please indicate your actual opinion about the cost factor of 4IR technology adoption and its potential effects on your company.

C1. The most important factor for our company is the low acquisition costs of 4IR technology.

C2. The costs for training employees to use 4IR technology are very high.

C3. The costs for business process improvement in terms of 4IR technology adoption are very high.

C4. The costs of maintaining 4IR technologies will be prohibitively high.

C5. The costs of implementing 4IR technologies for our suppliers will be high.

PART V: ORGANIZATIONAL CONTEXT

SECTION D – TOP MANAGEMENT SUPPORT

Please indicate your actual opinion about the top management support factor of 4IR technology adoption (refer definition at top page) and its potential effects on your company.

D1. Our top management is likely to invest funds in 4IR technology adoption.

D2. Our top management is willing to take risks in adopting 4IR technologies.

D3. Our top management is likely to be interested in 4IR technology adoption in order to gain a competitive advantage.

D4. Our top management is likely to consider 4IR technology adoption as strategically important.

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SECTION E – FIRM SIZE

Please indicate your opinion about the size of a company as a factor of 4IR technology adoption.

E1. In our opinion, small organizations are more flexible in adopting 4IR technologies.

E2. The number of employees in our company is high compared to others in the industry.

E3. Our annual sales turnover is high compared to others in the industry.

PART VI: ENVIRONMENTAL CONTEXT

SECTION F – COMPETITIVE PRESSURE

Please indicate your opinion about the competitive pressure as a factor of 4IR technology adoption (refer definition at top page).

F1. Our customers can easily switch to another company for similar products/ services.

F2. Our customers are able to easily access several existing products/ services which are different from ours but perform the same functions.

F3. There is intense rivalry among companies in the industry in terms of 4IR technology adoption.

F4. Some of our competitors have already started using 4IR technologies.

F5. Our company is under pressure from customers to adopt 4IR technology.

F6. Our company is under pressure from competitors to adopt 4IR technology.

F7. Our company is under pressure from suppliers to adopt 4IR technology.

F8. Our company is under pressure from our partners to adopt 4IR technology.

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SECTION G – GOVERNMENT SUPPORT

Please indicate your actual opinion about the Government support factor of 4IR technology adoption (refer definition at top page) and its potential effects on your company.

G1. Government policies provide effective initiatives to promote our company to adopt 4IR technologies.

G2. The Government provides education and training programs related personnel to motivate our company to adopt 4IR technologies.

G3. The Government provides financial incentives (e.g. funds, grants, subsidies etc.) to encourage our company to adopt 4IR technologies.

G4. These financial incentives (e.g. funds, grants, subsidies etc.) are processed promptly enough for our company to adopt 4IR technologies.

G5. The Government agencies monitor our company's commitment to adopt 4IR technologies.

G6. The Government actively supports the adoption of 4IR technologies by the industry.

PART VII: ADOPTION OF 4IR TECHNOLOGIES

For PART VII, kindly CHOOSE ONE of the statements that best describes your company.

1. 4IR technology adoption for our company is currently at:
- Have already adopted services, infrastructure, or platforms of 4IR technologies.
- Currently evaluating implementation (e.g., in a pilot study).
- Have evaluated and planning to adopt 4IR technologies.
- Have evaluated but decided NOT to adopt 4IR technologies.
- Not considering at all.

2. If our company has adopted/will adopt (more) 4IR technologies in the future, it is expected to happen (when):
- In less than 1 year
- Between 1 and 2 years
- Between 3 and 5 years
- More than 5 years

3. The number of 4IR technologies have been/will be adopted by our company:
- More than 6 types
- Between 4 to 5 types
- Between 2 to 3 types
- 1 type

4. Our company's frequency usage levels when applying adopted 4IR technology towards any related job:
    - Used Extensively
    - Used Frequently
    - Used Quite Often
    - Used Rarely
    - Not Used At All

5. Total time spent by our company in a day using the adopted 4IR technology towards any related jobs:
    - All the time
    - 5 to 7 hours daily
    - 2 to 4 hours daily
    - Less than two hours daily
    - Not used at all

6. If our company has adopted/will adopt any of the following 4IR technologies, please choose all that apply (and its objective(s) in the next question):
    - Advanced materials and technology
    - Artificial intelligence (AI)
    - Big data analytics (BDA)
    - Blockchain
    - Cloud computing
    - Internet of things (IoT)
    - Other services, platforms, or infrastructure

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7. If our company has adopted/will adopt any of the above-mentioned (in question 4 on this page) 4IR technologies, these are the objective(s) that apply:
    - Production or service operations planning & quality control
    - Functions specific to our industry
    - Administrative functions (HR, finance, accounting etc.)
    - Sourcing, procurement, and supply chain management
    - Sales, marketing and product/service development
    - Payment
    - After sale services (e.g. warranty, customer service)

The next question would only appear for respondents who chose the following answers for question 1 in PART VII. [1]. 4IR technology adoption for our company is currently at:

- Have evaluated but decided NOT to adopt 4IR technologies.
- Not considering at all.

8. The **MAIN FACTOR** our company decided NOT to adopt/consider 4IR technologies is because:

- Relative advantage
- Complexity
- Cost
- Top management support
- Firm size
- Government support
- Competitive pressure

END OF SURVEY - click to submit your questionnaire.

Thank you for taking your time to respond to this survey. For any queries, please contact me via my email at azrin_adlina@oyagsb.uum.edu.my.

Feedbacks welcome in the space allotted below.

Your response has been submitted. Thank you.

END

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Appendix B

Soal Selidik (Bahasa Melayu)

SOAL SELIDIK PKS: PENERIMAGUNAAN TEKNOLOGI 4IR (REVOLUSI INDUSTRI KE-4) DAN JENIS STRATEGI SYARIKAT

YBhg. Dato'/YBrs. Dr./Tuan/Puan,

Sukacita dimaklumkan syarikat YBhg. Dato'/YBrs. Dr./Tuan/Puan telah terpilih sebagai responden di dalam kajian ini. Soal selidik akademik ini bertujuan untuk mendapatkan pandangan syarikat kecil dan sederhana (PKS). **PKS merangkumi syarikat yang mempunyai pekerja sepenuh masa melebihi 5 orang dalam pelbagai industri.** Adalah diharapkan hasil kajian ini akan dapat memahami faktor penerimagunaan teknologi 4IR (revolusi industri ke-4) dan jenis strategi di kalangan PKS. Ia hanya memerlukan masa 15-20 minit untuk dilengkapkan.

Adalah dipohon **wakil daripada pihak pengurusan** sebagai responden kepada soal selidik ini. Kerjasama YBhg. Dato'/Tuan/Puan dalam memberi pandangan ke arah pemantapan dasar 4IR dan PKS negara amatlah dihargai dan didahului dengan ucapan jutaan terima kasih.

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Sebarang **respon kepada soal selidik adalah RAHSIA** dan tidak akan dapat dikaitkan kembali kepada pihak YBhg. Dato'/YBrs. Dr./Tuan/Puan, mahupun pihak syarikat. Ia hanya akan digunakan secara agregat/terkumpul dan terhad bagi tujuan analisis kajian sahaja. Jika YBhg. Dato'/YBrs. Dr./Tuan/Puan ingin menariks diri daripada menyertai soal selidik ini atau mempunyai sebarang kemusykilan mengenai soal selidik ini, sila hubungi saya melalui azrin_adlina@oyagsb.uum.edu.my.

Sekian. Terima kasih.

Yang Benar,
Azrin Zainol Calon PhD
Pusat Pengajian Pengurusan Teknologi dan Logistik (STML)
Universiti Utara Malaysia (UUM)

BAHAGIAN I: DEMOGRAFIK - RESPONDEN

Bahagian ini mengumpulkan maklumat demografik responden. Sila pilih jawapan yang sesuai.

1. Sila nyatakan nama syarikat anda: _____

2. Sila nyatakan alamat emel (pilihan): _____

3. Sila pilih (2 maksimum) jawatan yang anda pegang dalam syarikat (pada masa ini):
   - Pemilik
   - Ketua Pegawai Eksekutif/Pengarah Urusan
   - Pengurusan Tertinggi/Pengurus Peringkat Eksekutif (C-suite)/Rakan Kongsi
   - Ketua Jabatan/Pengurus
   - Tahap Eksekutif
   - Setiausaha/Pentadbiran

4. Sila nyatakan tempoh anda memegang jawatan ini:
   - Kurang daripada 3 tahun
   - 3 – 5 tahun
   - 6 – 10 tahun
   - 11 – 15 tahun
   - Lebih 15 tahun

5. Pernahkah anda terlibat secara bermakna di dalam aktiviti pembangunan strategi syarikat?
   - Ya
   - Tidak

6. Sila nyatakan kelayakan akademik tertinggi anda:
   - Sijil Persekolahan
   - Diploma/Sijil Profesional
   - Ijazah Sarjana Muda
   - Ijazah Sarjana
   - Ijazah Kedoktoran

7. Nyatakan jantina anda:
   - Lelaki
   - Perempuan

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BAHAGIAN II: TIPOLOGI (JENIS) STRATEGI SYARIKAT

Bagi BAHAGIAN II, sila PILIH SATU pernyataan yang paling sesuai dengan syarikat anda.

1. Berbanding pesaing lain, produk dan/atau perkhidmatan yang kami berikan kepada pelanggan kami adalah:
    - Amat fokus, stabil & konsisten di keseluruhan syarikat/pasaran.
    - Agak stabil di beberapa unit/jabatan /pasaran tertentu, namun inovatif selain daripada itu.
    - Lebih inovatif, sentiasa berubah dan lebih generik/umum sifatnya.
    - Berubah-ubah dan amnya berpandukan peluang/ancaman pasaran/persekitaran.

2. Jumlah masa dan sumber yang syarikat kami peruntukkan untuk memantau perubahan dan trend pasaran boleh disifatkan dengan tepat sebagai:
    - Berterusan: Kami sentiasa memantau pasaran.
    - Sederhana: Kami luangkan masa sewajarnya bagi memantau pasaran.
    - Terhad: Kami jarang meluangkan masa untuk memantau pasaran.
    - Tidak menentu: Adakalanya, kami meluangkan masa yang lama bagi memantau pasaran tetapi pada masa yang lain, kami meluangkan masa yang singkat.

3. Berbanding dengan pesaing, imej kami di pasaran adalah bahawa kami:
    - Bertindak balas terhadap peluang atau ancaman di dalam pasaran, sama ada untuk mengekalkan atau mempertingkatkan kedudukan kami.
    - Mempunyai reputasi berinovasi dan kreatif.
    - Mengguna pakai idea baharu dan berinovasi tetapi hanya setelah analisis yang teliti.
    - Menawarkan produk/perkhidmatan terhad yang terpilih dari segi kualitinya.

4. Berbanding syarikat lain, peningkatan atau penurunan permintaan terhadap produk/perkhidmatan kami kebanyakannya berpunca daripada amalan kami:
    - Menumpukan lebih kepada membangunkan sepenuhnya pasaran sedia ada kami.
    - Menembusi pasaran sedia ada kami dengan lebih mendalam secara agresif, tetapi juga dalam mengguna pakai produk/perkhidmatan baharu setelah mempertimbangkan potensinya dengan teliti.
    - Memasuki pasaran baru secara agresif dengan produk/perkhidmatan yang baharu.
    - Bertindak balas terhadap tekanan pasaran dengan mengambil risiko minimum.

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5. Salah satu daripada sasaran utama syarikat ini ialah dedikasi dan komitmen kami terhadap:
    - Memastikan modal insan, sumber dan peralatan diperlukan untuk membangunkan produk/perkhidmatan baru atau masuk ke pasaran baru disediakan dan boleh diakses.
    - Menganalisis kos dalam pendapatan dengan teliti agar kos terkawal dan bagi menjana produk/perkhidmatan baru secara terpilih atau masuk ke pasaran baru.
    - Pastikan kos di bawah kawalan.
    - Pastikan kami berwaspada terhadap ancaman kritikal dengan bertindak sewajarnya.

6. Berbanding syarikat lain, kompetensi (kemahiran) yang dimiliki pihak pengurusan kami disifatkan sebagai:
    - Berubah-ubah: kemahiran mereka selari dengan permintaan pasaran jangka pendek.
    - Meluas dan bersifat keusahawanan: kemahiran mereka adalah pelbagai, anjal/fleksibel dan membolehkan perubahan berlaku.
    - Kritis: kemahiran mereka membolehkan mereka mengenal pasti trend dan kemudian membangunkan produk/perkhidmatan atau pasaran baru.
    - Khusus: kemahiran mereka tertumpu kepada satu atau hanya beberapa bidang tertentu.

7. Satu perkara yang melindungi syarikat kami daripada pesaing adalah kebolehan kami:
    - Melakukan beberapa perkara dengan sangat cemerlang.
    - Menganalisis trend memuncul dengan teliti tetapi melaksanakan hanya yang terbukti berpotensi.
    - Membangunkan produk/perkhidmatan/pasaran baharu secara konsisten.
    - Bertindak balas terhadap trend walaupun peluang trend itu berlaku adalah sederhana.

8. Berbanding syarikat lain, pihak pengurusan kami cenderung memfokus kepada:
    - Membangunkan produk/perkhidmatan baru dan memasuki pasaran/segmen baru.
    - Menganalisis peluang pasaran dan memilih hanya peluang yang terbukti berpotensi, sambil mempertahankan kedudukan kewangan yang teguh.
    - Mengekalkan status kewangan yang teguh melalui langkah kawalan kos dan kualiti.
    - Aktiviti atau fungsi perniagaan yang paling memerlukan perhatian; bergantung kepada peluang atau masalah yang sedang kami hadapi.

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9. Berbanding syarikat lain, kami bersiap sedia demi masa depan dengan mengenal pasti:
    - penyelesaian terbaik terhadap masalah/cabaran yang perlukan perhatian serta merta.
    - trend dan peluang yang boleh membawa kepada penawaran produk/perkhidmatan baru kepada industri atau memasuki pasaran baru.
    - trend industri yang pesaing kami telahpun buktikan potensi jangka panjangnya, serta menyelesaikan masalah berkaitan produk/perkhidmatan dan keperluan pelanggan.
    - masalah yang mana jika diselesaikan, akan mengekalkan dan mempertingkatkan penawaran produk/perkhidmatan dan kedudukan pasaran kami.

10. Berbanding pesaing kami, struktur organisasi syarikat kami adalah:
    - Mengikut fungsi (cthnya: mengikut jabatan – pemasaran, perakaunan, dll.)
    - Struktur hibrid/kacukan (cth: amnya mengikut fungsi), tetapi bagi bidang penawaran produk/perkhidmatan yang agak baru atau lebih besar, ia berdasarkan kategori produk/perkhidmatan atau, berorientasikan pasaran.
    - Berdasarkan kategori produk/perkhidmatan atau berorientasikan pasaran.
    - Sentiasa berubah agar membolehkan kami meraih peluang dan menyelesaikan masalah yang timbul.

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11. Prosedur yang syarikat kami gunakan untuk menilai prestasi tepat dihuraikan sebagai:

    - Ternyahpusat/terpencar dan penyertaan/partisipatori; menggalakkan ramai ahli organisasi untuk melibatkan diri.
    - Hibrid/Kacukan; berpusatkan produk/perkhidmatan yang lebih stabil manakala lebih partisipatori/penyertaan dalam produk/perkhidmatan yang agak baru.
    - Sangat berpusat dan tertumpu kepada tanggung jawab pihak pengurusan kanan.
    - Amat cenderung mengikut keperluan pelaporan yang diperlukan pada kadar segera

BAHAGIAN III: PROFIL SYARIKAT

Bahagian ini berkaitan dengan PROFIL SYARIKAT anda. Sila pilih jawapan yang paling tepat.

1. Pemilikan syarikat anda seperti didaftarkan dengan Suruhanjaya Syarikat Malaysia – SSM:
    - Sendirian Berhad
    - Pemilikan Tunggal
    - Perkongsian
    - Perkongsian Liabiliti Terhad

2. Bilangan tahun sejak syarikat ditubuhkan:
    - Kurang daripada 3 tahun
    - 3 – 5 tahun
    - 6 – 10 tahun
    - 11 – 15 tahun
    - Lebih 15 tahun

3. Pilih lokasi ibu pejabat syarikat:
    - Johor
    - Kedah
    - Kelantan
    - Melaka
    - Negeri Sembilan
    - Pahang
    - Perak
    - Perlis
    - Pulau Pinang
    - Sabah
    - Sarawak
    - Selangor
    - Terengganu
    - WP Kuala Lumpur
    - WP Labuan
    - WP Putrajaya

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4. Pilih jenis kawasan ketempatan/lokaliti syarikat:
    - Bandar
    - Sub-bandar
    - Luar Bandar

5. Sektor utama industri syarikat anda: (Pilih sama ada pembuatan atau perkhidmatan)
    - Perkhidmatan
    - Pembuatan

6. Jika PERKHIDMATAN adalah sektor perindustrian UTAMA syarikat anda:
    - Kesenian, Hiburan & Rekreasi
    - Pendidikan
    - Makanan & Minuman dan Penginapan
    - Kesihatan
    - Teknologi Maklumat & Komunikasi
    - Profesional (kewangan, insurans, perkhidmatan perniagaan) & Hartanah
    - Pengangkutan & Penyimpanan
    - Utiliti/Tenaga
    - Perdagangan Borong & Runcit

7. Jumlah Jualan Tahunan (syarikat perkhidmatan):
    - RM300,000 hingga RM3 juta
    - RM3 juta hingga RM20 juta

8. Jumlah pekerja sepenuh masa (syarikat perkhidmatan):
    - Di antara 5 hingga 30 pekerja
    - Di antara 30 hingga 75 pekerja

9. Jika PEMBUATAN adalah sektor perindustrian utama syarikat anda:
    - Produk asas tani dan makanan
    - Industri Simen & Bahan Bangunan
    - Produk Peralatan Elektrik & Elektronik
    - Perabot & produk kayu
    - Industri Geometri & Elektrikal dan Industri Besi
    - Mesin dan kelengkapan
    - Industri berasaskan sumber
    - Perkhidmatan Berkaitan Pembuatan
    - Tekstil dan pakaian

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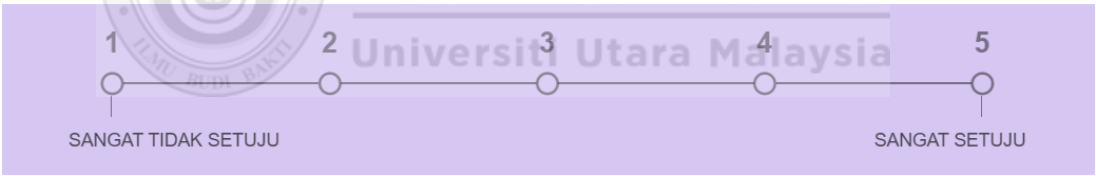
10. Jumlah Jualan Tahunan (syarikat pembuatan):
    - Di antara RM300,000 hingga RM15 juta
    - Di antara RM15 juta hingga RM50 juta

11. Jumlah pekerja sepenuh masa (syarikat pembuatan):
    - Di antara 5 hingga 75 pekerja sepenuh masa
    - Di antara 75 hingga 200 pekerja sepenuh masa

DEFINISI TEKNOLOGI 4IR dalam kajian ini merujuk kepada teknologi tertentu sebagaimana dikenal pasti di dalam Dasar Revolusi Industri ke-4 yang dilancarkan pada 2021 seperti AI, Analitik Data Raya, Pengkomputeran Awan, platform *e-commerce*, dll.

DEFINISI PENERIMAGUNAAN (*ADOPTION*) teknologi dalam kajian ini merujuk kepada tahap kegunaan teknologi dipilih (semasa/di masa hadapan) oleh sesebuah syarikat sama ada melalui pemilikan atau langganan.

Sila jawab dengan memilih satu nombor di skala interval Likert 1-5 dan dilabel Sangat Tidak Setuju [1], Tidak Setuju [2], Neutral [3], Setuju [4] dan Sangat Setuju [5].



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BAHAGIAN IV: KONTEKS TEKNOLOGI

SEKSYEN A - FAEDAH BERBANDING/RELATIF

Istilah: Faedah berbanding/relatif (*Relative Advantage*) adalah "sejauh mana teknologi 4IR dianggap lebih baik daripada idea sebarang teknologi lain yang digantikannya". Keuntungan ekonomi, prestij sosial dan faedah teknologi diungkapkan sebagai faedah berbanding/relatif.

Sila nyatakan pendapat anda mengenai faedah berbanding atau potensi penerimagunaan (*adoption*) teknologi 4IR terhadap syarikat anda. Rujuk definisi 4IR di bahagian atas halaman ini.

A1. Teknologi 4IR mempertingkatkan kualiti kerja syarikat kami.
A2. Teknologi 4IR menjadikan kerja kami lebih efisien.

A3. Teknologi 4IR menjimatkan kos menjalankan perniagaan kami.
A4. Teknologi 4IR mempertingkatkan kualiti khidmat pelanggan kami.
A5. Teknologi 4IR menarik jualan atau pelanggan atau pasaran baharu kepada syarikat kami.
A6. Teknologi 4IR mengenal pasti peluang baru produk/ perkhidmatan bagi syarikat kami.

SEKSYEN B - KOMPLEKSITI/KERUMITAN

Istilah: Kompleksiti *(complexity)* adalah sejauh mana teknologi 4IR dianggap sebagai lebih sukar difahami dan digunakan berbanding teknologi yang digantikannya.

Sila nyatakan pendapat anda mengenai faktor kompleksiti/kerumitan atau potensi penerimagunaan (*adoption*) teknologi 4IR terhadap syarikat anda. Rujuk definisi di bahagian atas halaman ini.

B1. Skil/Kemahiran yang diperlukan untuk menggunakan teknologi 4IR adalah terlalu rumit/kompleks bagi pekerja kami.
B2. Skil yang diperlukan untuk melaksanakan teknologi 4IR adalah terlalu rumit/ kompleks bagi syarikat kami.
B3. Mengintegrasikan teknologi 4IR ke dalam amalan kerja kami akan menimbulkan cabaran.

SEKSYEN C – KOS

Istilah: Kos penerimagunaan (*adoption*) bergantung kepada teknologi dan merangkumi kos penetapan dan pemasangan; perkakasan (*hardware*) dan perisian (*software*); perekrutan pekerja; kos latihan; serta kos tidak langsung seperti kos peralihan dan pentadbiran yang perlu ditanggung oleh syarikat tersebut.
Sila nyatakan pendapat anda mengenai faktor kos atau potensi penerimagunaan (*adoption*) teknologi 4IR terhadap syarikat anda.

C1. Faktor paling penting bagi syarikat kami ialah kos perolehan yang rendah bagi teknologi 4IR.
C2. Kos melatih pekerja kami untuk menggunakan teknologi 4IR adalah sangat tinggi.
C3. Kos menaik taraf proses perniagaan dari penerimagunaan teknologi 4IR adalah sangat tinggi bagi syarikat kami.
C4. Kos penyelenggaraan teknologi 4IR akan menjadi terlalu tinggi untuk ditanggung bagi syarikat kami.
C5. Kos melaksanakan teknologi 4IR bagi pembekal kami adalah sangat tinggi.

SEKSYEN D - SOKONGAN PENGURUSAN TERTINGGI

Sila nyatakan pendapat anda mengenai faktor sokongan pihak pengurusan tertinggi atau potensi penerimagunaan (*adoption*) teknologi 4IR terhadap syarikat anda. Rujuk definisi di bahagian atas halaman ini.

D1. Pihak pengurusan tertinggi kami mungkin akan melabur dana di bagi penerimagunaan teknologi 4IR.
D2. Pihak pengurusan tertinggi kami sanggup menanggung risiko penerimagunaan teknologi 4IR.
D3. Pihak pengurusan tertinggi kami mungkin akan berminat untuk penerimagunaan teknologi 4IR supaya dapat meraih kelebihan saingan.
D4. Pihak pengurusan tertinggi kami mungkin akan berpendapat penerimagunaan teknologi 4IR adalah penting secara strategiknya.

SEKSYEN E - SAIZ SYARIKAT

Sila nyatakan pendapat anda mengenai faktor saiz syarikat atau potensi penerimagunaan (*adoption*) teknologi 4IR terhadap syarikat anda.

E1. Organisasi kecil lebih fleksibel dalam penerimagunaan teknologi 4IR.
E2. Bilangan pekerja syarikat kami adalah tinggi berbanding perusahaan lain di dalam industri.
E3. Jumlah jualan tahunan syarikat kami adalah tinggi berbanding yang lain di dalam industri.

BAHAGIAN VI: KONTEKS PERSEKITARAN

SEKSYEN F - TEKANAN PERSAINGAN

Sila nyatakan pendapat anda mengenai faktor sokongan pihak pengurusan tertinggi atau potensi penerimagunaan (*adoption*) teknologi 4IR terhadap syarikat anda. Rujuk definisi di bahagian atas halaman ini.

F1. Pelanggan kami dengan mudah bertukar kepada syarikat lain bagi produk/perkhidmatan yang serupa.
F2. Pelanggan kami dengan mudah dapat memperolehi beberapa produk/perkhidmatan sedia ada yang berbeza daripada syarikat kami namun mempunyai fungsi yang sama.
F3. Terdapat persaingan yang hebat di kalangan syarikat dalam industri ini dalam penerimagunaan teknologi 4IR.
F4. Sesetengah pesaing kami telahpun mula menggunakan teknologi 4IR.
F5. Syarikat kami menerima tekanan daripada pelanggan dalam penerimagunaan teknologi 4IR.
F6. Syarikat kami menerima tekanan daripada pesaing dalam penerimagunaan teknologi 4IR.

F7. Syarikat kami menerima tekanan daripada pembekal dalam penerimagunaan teknologi 4IR.
F8. Syarikat kami menerima tekanan daripada rakan kongsi dalam penerimagunaan teknologi 4IR.

SEKSYEN G - SOKONGAN KERAJAAN

Sila nyatakan pendapat anda mengenai faktor sokongan pihak pengurusan tertinggi atau potensi penerimagunaan (*adoption*) teknologi 4IR terhadap syarikat anda. Rujuk definisi di bahagian atas halaman ini.

G1. Dasar kerajaan menyediakan inisiatif berkesan untuk menggalakkan penerimagunaan teknologi 4IR syarikat kami.
G2. Kerajaan menyediakan kakitangan berkaitan program pendidikan dan latihan untuk menggalakkan penerimagunaan teknologi 4IR syarikat kami.
G3. Kerajaan menyediakan insentif kewangan (cthnya: dana, geran, subsidi, dll.) untuk menggalakkan penerimagunaan teknologi 4IR syarikat kami.
G4. Insentif kewangan ini diproses dengan cukup segera untuk menggalakkan penerimagunaan teknologi 4IR syarikat kami.
G6. Agensi kerajaan memantau komitmen penerimagunaan teknologi 4IR syarikat kami.
G7. Kerajaan secara aktif menyokong penerimagunaan teknologi 4IR dalam industri.

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BAHAGIAN VII: PENERIMAGUNAAN *(ADOPTION)* TEKNOLOGI 4IR

Bagi BAHAGIAN VII, sila PILIH SATU daripada pernyataan berikut yang paling sesuai menghuraikan syarikat anda:

1. Tahap penglibatan penerimagunaan (*adoption*) teknologi 4IR di syarikat kami:
    - Penerimagunaan perkhidmatan, infrastruktur, atau platform teknologi 4IR telah berlaku.
    - Sedang dinilai pelaksanaannya (cthnya: kajian perintis)
    - Penerimagunaan teknologi 4IR telahpun dinilai dan sedang dalam perancangan.
    - Penerimagunaan teknologi 4IR telahpun dinilai tetapi diputuskan untuk ditolak.
    - Tidak akan dipertimbangkan langsung.

2. Jika syarikat kami telahpun menerima guna atau menjangkakan penerimagunaan (adoption) teknologi 4IR, ia telah/mungkin akan berlaku dalam tempoh:
    - Kurang daripada setahun
    - Di antara 1 hingga 2 tahun
    - Di antara 2 hingga 5 tahun
    - Lebih daripada 5 tahun

3. Bilangan teknologi 4IR yang akan/telah diterima guna (adoption) oleh syarikat kami:
    - Lebih daripada 5 jenis
    - 4 hingga 5 jenis
    - 2 hingga 3 jenis
    - 1 jenis

4. Tahap kekerapan penggunaan teknologi 4IR oleh syarikat kami di dalam sebarang kerja yang berkaitan:
    - Digunakan secara meluas
    - Sangat kerap digunakan
    - Agak kerap digunakan
    - Jarang digunakan
    - Tidak digunakan langsung

5. Jumlah jam dalam sehari di mana syarikat kami menggunakan teknologi 4IR di dalam sebarang kerja berkaitan:
    - Sepanjang masa
    - 5 hingga 7 jam sehari
    - 2 hingga 4 jam sehari
    - Kurang daripada 2 jam sehari
    - Tidak digunakan langsung

6. Jika syarikat kami telah/akan melaksanakan penerimagunaan (adoption) 4IR, berikut adalah semua teknologi tersebut (serta tujuannya dalam soalan seterusnya)
    - Bahan dan Teknologi Termaju (*Advanced Material and Technologies*)
    - Kecerdasan buatan (AI - *Artificial Intelligence*)
    - Data Raya (BDA - *Big Data Analytics*)
    - Blok rantai (*Blockchain*)
    - Pengkomputeran awan (*Cloud Computing*)
    - Internet Benda (IoT - *Internet of Things*)
    - Lain-lain perkhidmatan, infrastruktur, atau platform (cthnya: aplikasi, perisian berasaskan AI, e-dagang, e-pembayaran, e-wallet)

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7. Jika syarikat kami telah/akan melaksanakan penerimagunaan teknologi 4IR (dalam soalan 4 di halaman ini), sila pilih semua teknologi serta tujuan yang berkaitan:
    - Proses pengeluaran atau perancangan operasi perkhidmatan & kawalan kualiti
    - Fungsi yang khusus kepada industri kami
    - Fungsi pentadbiran (sumber manusia, kewangan, perakaunan, dll.)
    - Penyumberan, perolehan dan pengurusan rantaian sumber
    - Penjualan, Pemasaran dan pembangunan produk/perkhidmatan
    - Pembayaran
    - Perkhidmatan Selepas Jualan (Cth: Jaminan, perkhidmatan pelanggan)

Soalan seterusnya hanya akan muncul bagi responden yang memilih dua jawapan terakhir (seperti berikut) bagi BAHAGIAN VII [1]. Tahap penglibatan penerimagunaan (*adoption*) teknologi 4IR di syarikat kami:

- Penerimagunaan teknologi 4IR telahpun dinilai tetapi diputuskan untuk ditolak.
- Tidak akan dipertimbangkan langsung.

8. Faktor utama syarikat kami membuat keputusan menolak/tidak mempertimbangkan penerimagunaan teknologi 4IR ialah kerana:
    - Faedah relatif
    - Kompleksiti/Kerumitan
    - Kos
    - Sokongan Pihak Pengurusan Tertinggi
    - Saiz Syarikat
    - Tekanan Persaingan
    - Sokongan Kerajaan

SOAL SELIDIK TAMAT - Sila klik butang untuk hantar soal selidik anda.
Terima kasih diucapkan di atas masa yang diluangkan untuk menjawab soal selidik ini. Jika terdapat sebarang kemusykilan, sila hubungi saya melalui emel azrin_adlina@oyagsb.uum.edu.my.

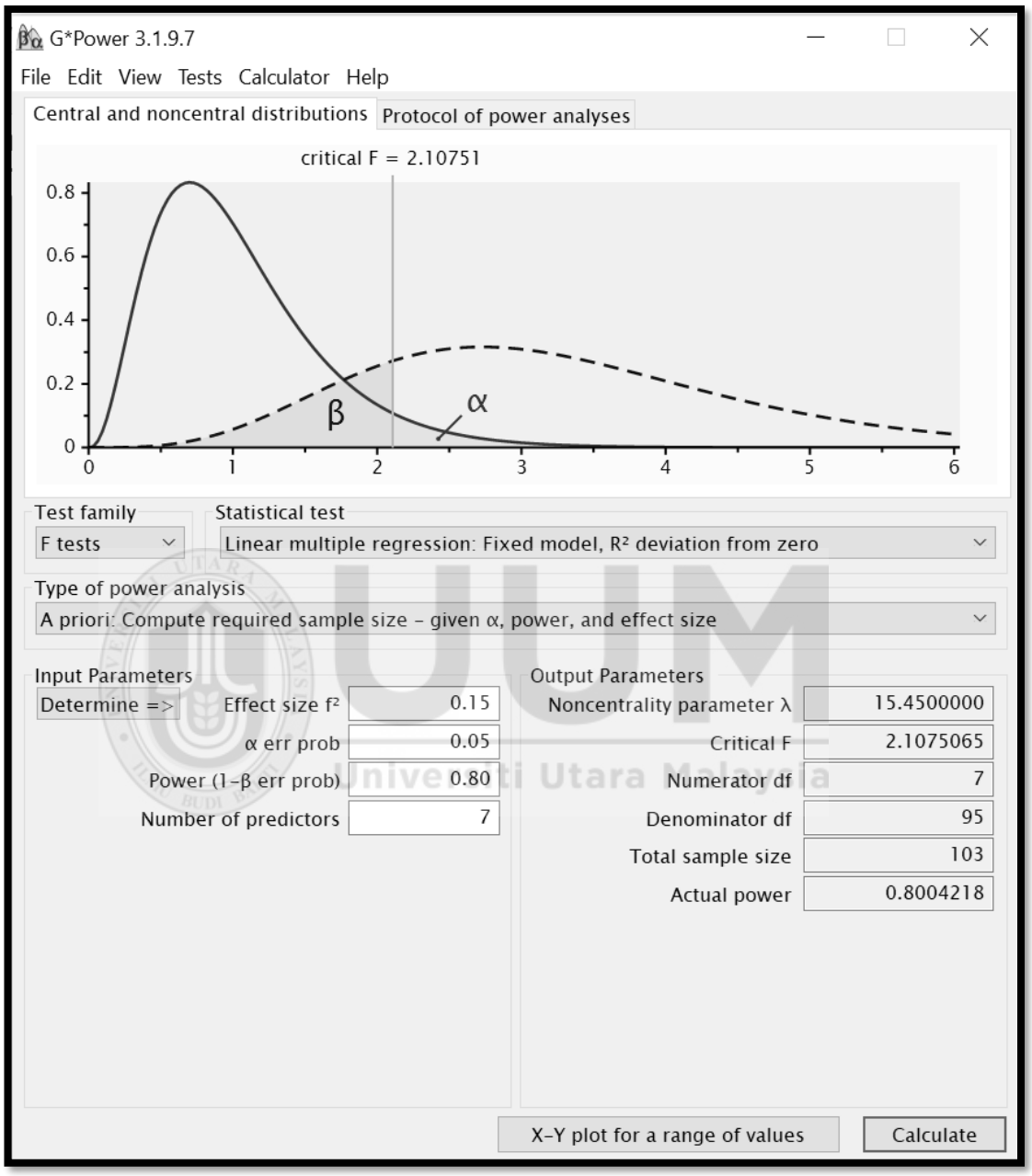
Maklumbalas juga boleh dinyatakan di ruang di bawah.
Respons anda telah dihantar. Terima kasih.
.

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Appendix C

G*Power Calculation for Sample Size



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Appendix D

Multivariate Outlier Detection with Mahalanobis Distance (D2)

ID No.	MAH_D^2	Probability_ D^2	OUTLIER_ D^2
1	1.90559	0.03512	0
2	1.99675	0.03998	0
3	4.37396	0.26416	0
4	4.63030	0.29502	0
5	4.84036	0.32056	0
6	9.55267	0.78463	0
7	8.94066	0.74306	0
8	1.31130	0.01187	0
9	10.11080	0.81762	0
10	6.88138	0.55867	0
11	3.61572	0.17718	0
12	16.82824	0.98146	0
13	4.49565	0.27876	0
14	21.15885	0.99646	0
15	11.18352	0.86919	0
16	2.26974	0.05658	0
17	2.86431	0.10274	0
18	1.74070	0.02721	0
19	3.27101	0.14115	0
20	6.46782	0.51370	0
21	1.42481	0.01520	0
22	2.16254	0.04970	0
23	4.56384	0.28698	0
24	2.52879	0.07509	0
25	3.29163	0.14322	0
26	17.29306	0.98440	0
27	2.76501	0.09414	0
28	5.59131	0.41181	0
29	4.19677	0.24314	0
30	15.31743	0.96786	0
31	2.02342	0.04147	0
32	8.25443	0.68931	0
33	8.82882	0.73482	0
34	8.82878	0.73482	0
35	7.75633	0.64543	0
36	4.12565	0.23480	0
37	4.80022	0.31567	0
38	12.85768	0.92435	0
39	1.83109	0.03141	0
40	8.75915	0.72959	0
41	6.88603	0.55916	0

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Multivariate Outlier Detection with Mahalanobis Distance (D^2) – (*continued*)			
ID No.	**MAH_D^2**	**Probability_ D^2**	**OUTLIER_ D^2**
42	3.96299	0.21597	0
43	6.92948	0.56374	0
44	24.81232	0.99918	0
45	14.33935	0.95454	0
46	19.61281	0.99353	0
47	2.86529	0.10282	0
48	7.95935	0.66381	0
49	5.04347	0.34534	0
50	3.80391	0.19793	0
51	7.10377	0.58184	0
52	7.08478	0.57989	0
53	4.60757	0.29227	0
54	2.69130	0.08798	0
55	2.66069	0.08548	0
56	7.63980	0.63458	0
57	8.09533	0.67574	0
58	3.92514	0.21164	0
59	8.90852	0.74071	0
60	3.08038	0.12253	0
61	8.87718	0.73841	0
62	4.02031	0.22256	0
63	3.80141	0.19765	0
64	10.37614	0.83176	0
65	15.80192	0.97301	0
66	13.57756	0.94077	0
67	4.42876	0.27072	0
68	2.86431	0.10274	0
69	3.89345	0.20803	0
70	2.56899	0.07819	0
71	4.54928	0.28523	0
72	2.97721	0.11290	0
73	16.66932	0.98034	0
74	8.57778	0.71559	0
75	2.18473	0.05109	0
76	5.02559	0.34316	0
77	4.08859	0.23048	0
78	15.89270	0.97389	0
79	16.20831	0.97672	0
80	9.04501	0.75056	0
81	4.48438	0.27740	0
82	5.40480	0.38931	0
83	6.59690	0.52798	0

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Multivariate Outlier Detection with Mahalanobis Distance (D^2) – *(continued)*			
ID No.	**MAH_D^2**	**Probability_ D^2**	**OUTLIER_ D^2**
84	1.97052	0.03855	0
85	2.80778	0.09780	0
86	15.11861	0.96549	0
87	2.86431	0.10274	0
88	8.15834	0.68116	0
89	2.86431	0.10274	0
90	8.90123	0.74017	0
91	15.16729	0.96609	0
92	2.72002	0.09036	0
93	6.90942	0.56163	0
94	8.03746	0.67070	0
95	12.44004	0.91301	0
96	4.49934	0.27920	0
97	13.46422	0.93843	0
98	2.06595	0.04390	0
99	13.75829	0.94435	0
100	12.48754	0.91438	0
101	5.37685	0.38592	0
102	4.46078	0.27457	0
103	1.98130	0.03913	0
104	5.91960	0.45083	0
105	2.86431	0.10274	0
106	13.58359	0.94090	0
107	1.67930	0.02455	0
108	7.83129	0.65229	0
109	6.96502	0.56747	0
110	2.95778	0.11112	0
111	3.37535	0.15175	0
112	6.28224	0.49279	0
113	8.92150	0.74166	0
114	8.62194	0.71905	0
115	10.67388	0.84651	0
116	2.69242	0.08808	0
117	11.29527	0.87375	0
118	3.60838	0.17638	0
119	1.45456	0.01616	0
120	3.05097	0.11975	0
121	12.58487	0.91711	0
122	0.61160	0.00107	0
123	10.08218	0.81604	0
124	3.96949	0.21672	0
125	4.76720	0.31165	0

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Multivariate Outlier Detection with Mahalanobis Distance (D^2) – (*continued*)			
ID No.	**MAH_D^2**	**Probability_ D^2**	**OUTLIER_ D^2**
126	2.60778	0.08124	0
127	12.80556	0.92301	0
128	7.49684	0.62096	0
129	7.98564	0.66614	0
130	2.05847	0.04347	0
131	2.88096	0.10421	0
132	2.69748	0.08849	0
133	13.38348	0.93670	0
134	9.70428	0.79404	0
135	4.81476	0.31744	0
136	5.76978	0.43313	0
137	10.93855	0.85868	0
138	2.95052	0.11046	0
139	10.44881	0.83547	0
140	3.36334	0.15052	0
141	10.09752	0.81689	0
142	19.51211	0.99327	0
143	7.11930	0.58343	0
144	6.58543	0.52672	0
145	10.44881	0.83547	0
146	5.91710	0.45054	0
147	2.86431	0.10274	0
148	4.13733	0.23617	0
149	18.46653	0.98997	0
150	4.68121	0.30120	0
151	2.18473	0.05109	0
152	8.35893	0.69799	0
153	2.10089	0.04595	0
154	9.38438	0.77378	0
155	15.86256	0.97360	0
156	9.34378	0.77109	0
157	9.77242	0.79816	0
158	5.09599	0.35175	0
159	1.59468	0.02115	0
160	5.76134	0.43212	0
161	10.34133	0.82996	0
162	4.75276	0.30989	0
163	6.22780	0.48658	0
164	12.34513	0.91023	0
165	6.93139	0.56394	0
166	8.84824	0.73626	0
167	4.04345	0.22524	0

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Multivariate Outlier Detection with Mahalanobis Distance (D^2) – *(continued)*			
ID No.	**MAH_D^2**	**Probability_ D^2**	**OUTLIER_ D^2**
168	5.24081	0.36940	0
169	10.44881	0.83547	0
170	2.99421	0.11446	0
171	12.77415	0.92219	0
172	2.05305	0.04315	0
173	2.04688	0.04280	0
174	2.76780	0.09438	0
175	10.93053	0.85832	0
176	3.04739	0.11942	0
177	2.18473	0.05109	0
178	9.89555	0.80543	0
179	16.79336	0.98122	0
180	2.81491	0.09842	0
181	3.53288	0.16827	0
182	7.37596	0.60919	0

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Appendix E

Measurement model assessment results

Construct Items	Loading	CR	AVE
ADOPT1	0.724	0.938	0.754
ADOPT2	0.885		
ADOPT3	0.886		
ADOPT4	0.923		
ADOPT5	0.908		
CMPLX1	0.894	0.924	0.803
CMPLX2	0.946		
CMPLX3	0.844		
COMP1	0.582	0.916	0.582
COMP2	0.584		
COMP3	0.660		
COMP4	0.783		
COMP5	0.880		
COMP6	0.905		
COMP7	0.791		
COMP8	0.842		
COST1	0.742	0.896	0.633
COST2	0.771		
COST3	0.792		
COST4	0.804		
COST5	0.865		
GOVT1	0.899	0.961	0.805

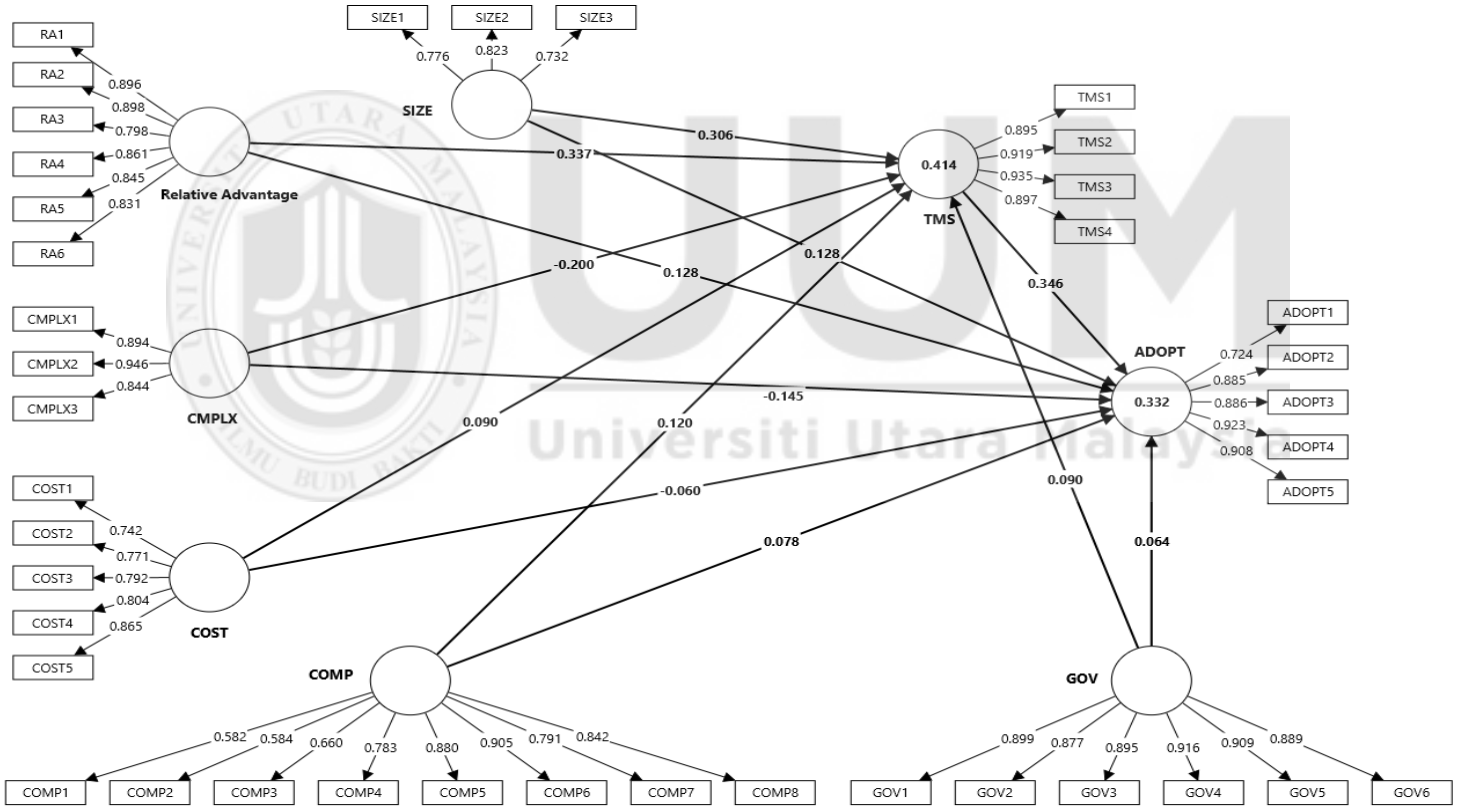
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Construct Items	Loading	CR	AVE
GOVT2	0.877		
GOVT3	0.895		
GOVT4	0.916		
GOVT5	0.909		
GOVT6	0.889		
RA1	0.896	0.942	0.732
RA2	0.898		
RA3	0.798		
RA4	0.861		
RA5	0.845		
RA6	0.831		
SIZE1	0.776	0.821	0.605
SIZE2	0.823		
SIZE3	0.732		
TMS1	0.895	0.952	0.831
TMS2	0.919		
TMS3	0.935		
TMS4	0.897		

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Appendix F

Graphical path diagram of the structural model



Source: Ringle, C. M., Wende, S., and Becker, J.-M. (2024). SmartPLS 4 [Software]

Appendix G

List of Fund, Grant and Subsidy for SMEs' Technology Adoption (2017-2025)

No.	Name of Financial Instrument	Start Year	Benefits	Total Amount	Source
1	SME Digitalization Initiative	2020	Subsidy for digital equipment, software, and digital transformation services	RM 500 million	SME Corp Malaysia. (2020). *SME Digitalization Initiative*. Retrieved from https://www.smecorp.gov.my
2	Industry4WRD Fund (Industry 4.0 Adoption Fund)	2018	Financial assistance for adopting Industry 4.0 technologies (automation, AI, etc.)	RM 200 million	Ministry of Investment, Trade and Industry (MITI). (2018). *Industry4WRD: A roadmap towards Industry 4.0*. Retrieved from https://www.miti.gov.my
3	Technology Acquisition Fund (TAF)	2017	Soft loans and grants for the acquisition of technologies/IP	RM 500 million	SME Corp Malaysia. (2017). *Technology Acquisition Fund (TAF)*. Retrieved from https://www.smecorp.gov.my
4	Smart Automation Grant (SAG)	2020	Grant for up to 50 percent of total cost for automation equipment and software	RM 100 million	Ministry of Finance Malaysia. (2020). *Penjana economic recovery plan*. Retrieved from https://www.treasury.gov.my
5	Digital Content Grant (DCG)	2017	Funding for digital content creation (animation, apps, games, etc.)	RM 60 million	Malaysia Digital Economy Corporation (MDEC). (2020). *Digital Content Grant*. Retrieved from https://www.mdec.my

No.	Name of Financial Instrument	Start Year	Benefits	Total Amount	Source
			(continued)		
6	Go Digital Programme	2019	Subsidy for adopting e-commerce platforms and digital marketing tools	RM 50 million	MDEC & SME Corp Malaysia. (2019). *Go Digital programme for SMEs*. Retrieved from https://www.mdec.my
7	Digital Transformation Acceleration Programme (DTAP)	2021	Assistance in technology adoption for operational efficiency; up to RM 300,000 grant	RM 50 million	SME Corp Malaysia. (2021). *Digital Transformation Acceleration Programme (DTAP)*. Retrieved from https://www.smecorp.gov.my
8	Malaysian Co-Investment Fund (MyCIF)	2018	Co-investment funding for tech startups and ventures	RM 100 million	Ministry of Finance Malaysia. (2018). *MyCIF: Malaysian Co-Investment Fund*. Retrieved from https://www.treasury.gov.my
9	Pembangunan Usahawan Bumiputera (Bumiputera Entrepreneur Development Fund)	2019	Financial support, including technology investments for Bumiputera entrepreneurs	RM 1 billion	Ministry of Finance Malaysia. (2019). *Bumiputera Entrepreneur Development Fund*. Retrieved from https://www.treasury.gov.my
10	E-commerce Adoption and Digitalization Incentive	2019	Financial aid for e-commerce platform adoption, digital marketing training	RM 100 million	MDEC. (2019). *E-commerce Adoption & Digitalization Incentive*. Retrieved from https://www.mdec.my
11	MYHI-TECH Fund (Malaysian High-Tech Fund)	2017	Subsidized loans or grants for the adoption of high-tech equipment and systems	RM 200 million	SME Corp Malaysia. (2017). *MYHI-TECH Fund*. Retrieved from https://www.smecorp.gov.my

No.	Name of Financial Instrument	Start Year	Benefits	Total Amount	Source
(continued)					
12	Innovation and Technology Fund (ITF)	2017	Grant support for SMEs adopting innovation to improve their business models	RM 300 million	Ministry of Science, Technology and Innovation (MOSTI). (2017). *Innovation and Technology Fund*. Retrieved from https://www.mosti.gov.my
13	Green Technology Financing Scheme (GTFS)	2017	Soft loans and tax incentives for green tech adoption and sustainable practices	RM 500 million	Ministry of Energy and Natural Resources (KeTSA). (2017). *Green Technology Financing Scheme (GTFS)*. Retrieved from https://www.ketsa.gov.my
14	SME Corp Malaysia's Digital Adoption Grant	2020	Subsidy for adoption of digital technologies for business optimization	RM 200 million	SME Corp Malaysia. (2020). *SME Corp Digital Adoption Grant*. Retrieved from https://www.smecorp.gov.my
15	Penjana Kapital Fund (Venture Capital Fund)	2020	Equity financing and venture capital for digital startups	RM 500 million	Ministry of Finance Malaysia. (2020). *Penjana Kapital Fund*. Retrieved from https://www.treasury.gov.my
16	Digital Infrastructure Fund	2021	Soft loans for infrastructure improvements related to technology adoption	RM 100 million	Ministry of Finance Malaysia. (2021). *Digital Infrastructure Fund*. Retrieved from https://www.treasury.gov.my
17	Technology and Innovation Fund (TIF)	2017	Loans and grants for SMEs researching or adopting new tech for market innovation	RM 100 million	Ministry of Science, Technology and Innovation (MOSTI). (2017). *Technology and Innovation Fund (TIF)*. Retrieved from https://www.mosti.gov.my

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No.	Name of Financial Instrument	Start Year	Benefits	Total Amount	Source
(continued)					
18	SME Technology Financing Scheme (TMF)	2017	Up to RM 5 million loan for technology adoption and innovation implementation	RM 1 billion	Bank Negara Malaysia. (2021). *SME Technology Financing Scheme (TMF)*. Retrieved from https://www.bnm.gov.my
19	Automated Teller Machine (ATM) Funding Scheme	2018	Financing for ATM deployment or mobile payment system installation	RM 200 million	Bank Negara Malaysia. (2021). *Automated Teller Machine (ATM) Funding Scheme*. Retrieved from https://www.bnm.gov.my

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Appendix H

List of Incubators and Accelerators (2023)

Ministry/state/agency	Programs
Ministry of Science, Technology and Innovation (MOSTI)	
CRADLE	MyStartup (pre-accelerator program) https://www.mystartup.gov.my/accelerator
MRANTI	• Global Accelerator Program • MRANTI Impact Challenge Accelerator Program https://mranti.my/global-accelerator-programme https://mranti.my/solutions/scaling-up-market-ready/mranti-impact-challenge-accelerator-mica
Bioeconomy Corporation	Bio-Based Accelerator Program https://www.bioeconomycorporation.my/industry-development/bio-based-accelerator-programme/overview/
Ministry of Entrepreneur Development and Cooperation (MEDAC)	
SMECorp	PRESTIGE https://www.smecorp.gov.my/index.php/en/programmes1/2015-12-21-09-53-14/prestige
Teraju (for Bumiputeras only)	SUPERB (2014 -2021) https://superb.teraju.gov.my/home https://vulcanpost.com/766347/teraju-superb-2021-bumiputera-startup-accelerator/

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Ministry/state/agency	Programs *(Continued)*
Ministry of Digital	
MDEC	• SME Digital Accelerator Program https://mdec.my/digital-economy-initiatives/for-the-industry/sme-digital-accelerator • GAIN (seven accelerator partners, which are either state or private programs) • Malaysia Tech Entrepreneur Program (MTEP) https://mdec.my/gain/accelerator-programs • 100 Soonicorns Program https://www.kkd.gov.my/en/public/news/23065-100-soonicorns-launched-to-expand-unicorn-club-in-malaysia • FOX program https://www.digitalnewsasia.com/startups/malaysias-unicorn-target-centres-around-mdecs-fox
Selangor state	Selangor Accelerator Program (5th cohort) https://www.sidec.com.my/sap2022/
Penang state	Penang Startup Accelerator Program (together with private) https://pydc.com.my/en/psap/

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Ministry/state/agency	Programs (Continued)
Sarawak	
Sarawak Digital Economy Corporation	Digital Village Accelerator https://diva.sarawak.digital/
Tabung Ekonomi Gagasan Anak Sarawak (TEGAS)	https://dayakdaily.com/tegas-to-groom-5-startups-in-its-startup-lab-accelerator-programme/
Malaysian Technology Development Corporation (MTDC)	I4.0 Accelerator Programs https://mytap.com.my/program_TAP-SME.php
Seven Public Universities; four with MTDC	• https://www.mtdc.com.my/technology-centre/ • USM: Centre for Innovation and Consultation (CIA) in collaboration with Western Digital https://innovations.usm.my/ https://www.nst.com.my/news/nation/2021/01/657929/western-digital-usm-unveil-centre-innovation-and-automation • University of Malaya Centre of Innovation & Enterprise (UMCIE) https://umcie.um.edu.my/
PETRONAS	Future Tech Accelerator Program https://www.petronas.com/ventures/futuretech-accelerator/

Source: (Tham, 2023)

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